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FOREWORD

The Australian Institute of Agricultural Science takes this opportunity in this Commonwealth Jubilee Year, to present a review of progress in agricultural research in the Commonwealth of Australia.

The need for agricultural research was appreciated from the early days of settlement. Through the years, increased numbers of trained scientists have been added to the staffs of the state departments of agriculture and research institutes. The formation of these departments and the growth of research facilities are discussed in this review.

The major fields of agricultural research—soils, pastures, crops and the livestock industries—are dealt with in turn, the section on crops including cereals, horticulture and vegetables. Control of insect pests and a discussion of fungicides and weedicides, because of their importance in all fields of agriculture, are also included.

A detailed account of the development of the schools of agriculture at the various Australian universities is presented, as these have played a vital part in the training of agricultural research workers and teachers.

Lastly, the history of the Australian Institute of Agricultural Science is included. Formed in 1935, *the Institute numbers amongst its membership most of the agricultural research workers in this country. It can now speak with authority on problems of Australian agriculture.*

THE DEVELOPMENT OF AGRICULTURAL RESEARCH IN AUSTRALIA

By B. T. DICKSON

It is well to recall from what small beginnings on January 26, 1788, our present agricultural production developed. One bull, one bull calf, four cows, one stallion, three mares, three colts, forty-four sheep, four goats, twenty-eight pigs, some fowls and turkeys, and a collection of plants and seeds constituted the first stock. Governor Phillip found among his people one farmer and a few who knew a little about farming to begin the task allotted to him—"It is therefore our will and pleasure that you do immediately upon your landing . . . proceed to the cultivation of the land. . . ."

The first farm was about nine acres in extent on the margin of a creek and is now incorporated in the Botanic Gardens, Sydney.

Colonisers in North America found some livestock such as the bison, crops such as maize, sweet potatoes and tobacco, but not so here. Everything had to be introduced for establishment and that has continued to be the case with very few exceptions. Thinking of such small beginnings fraught with so many difficulties one can only feel wonder and admiration at the truly magnificent achievement evident in Australian agriculture today, an achievement unequalled elsewhere if one considers the short stretch of time involved and the difficulties of production *de novo* in an antipodean hemisphere.

The need for Science in Agriculture

Research was of the self-help type, undoubtedly with the more thoughtful farmers assuming some leadership. Out of the difficulties inherent in such development, requests were made to colonial governments to establish demonstration farms and schools, to set up commissions and to employ experts under an authority. Farmers, too, began to form agricultural societies, looking for expert help as well as developing self-help. So in each colony the tendency to form a department of agriculture followed. In New South Wales experiment farms were established at Wagga, Bathurst, Wollongbar, etc., as a result of a report to the Minister for Mines about 1875, but five years later the Ministry and Department of Agriculture were created.

In Victoria a Vegetable Products Commission was set up in the eighties resulting in the appointment of certain experts who, with veterinarians and others, made the nucleus of the Department of Agriculture.

The Formation of State Departments of Agriculture

By the time the six colonies federated to form the Commonwealth and became states, each had a department of agriculture, four had agricultural colleges (Dookie and Longerenong 1884, Roseworthy 1885, Hawkesbury 1891 and Gatton 1897) and several had well established experiment farms. The principal need was for extension and demonstration with the added requirement of specialist and technical knowledge in certain fields, hence the appointment of experts who really became the first official research workers. Not all experts were scientifically trained but there were among them some outstanding men such as William Farrer, N. D. Cobb, D. McAlpine to name but three.

The Appointment of Scientifically Trained Specialists

It is since the beginning of the century that scientifically trained agriculturists began to be appointed to departments, particularly for livestock problems, plant disease control, insect pests, plant breeding, agricultural chemistry and so on. Gradually each department developed specialist staff in suitable branches charged with the responsibility for work with groups of crops such as fruit or horticultural crops, field crops, cereals, etc., or for special studies in scientific fields as entomology, plant pathology and plant breeding. These officers had to deal not only with research, but with extension and the dissemination of information by way of answers to queries, lectures and personal visits.

Reference should here be made to the result of the recommendation of one visiting expert in the establishment of the Bureau of Sugar Experiment Stations in Queensland under the Act of 1900.

The Establishment of Faculties of Agriculture at the Universities

The shortage of trained men in the early years and the gradual acceptance by farmers of scientifically trained rather than simply practical men focussed attention on the need to develop suitable schools of agriculture in the universities. Thus a University School of Agriculture was established in Adelaide in 1901, in Melbourne in 1906, and in Sydney in 1910 with the establishment of the first Chair of Agriculture in Australia. The graduates of these schools joined departments of agriculture and soon made their contributions to research, extension and administration. Had it not been for the compulsion of these men to engage in extension *ad hoc* research and administration, they could just as well have engaged in the prosecution of fundamental research as a full-time preoccupation with ultimate benefit to agriculture in that field. As it was the advances in agriculture in the technical sense at this stage were noteworthy, as is shown by the great development in production in Australia which occurred prior to, and even during, the 1914-18 war.

It was, however, in the next decade that major advances took place largely because of the evidence brought to public attention about the world food situation and the part to be played in it by Australia, which by then had demonstrated its beginning nationhood.

Three striking developments occurred during the 1925-27 period—the establishments of the Waite Agricultural Research Institute, the Development and Migration Commission and the Commonwealth Council for Scientific and Industrial Research.

The Waite Agricultural Research Institute

The Waite Agricultural Research Institute, made possible by the gift of Peter Waite to the University of Adelaide of lands, property and endowment, began active work in March, 1925, at Glen Osmond, S.A. Here was a practical illustration of the ideal of one man convinced that there was need for scientific work to improve the agricultural development of large areas in the State of South Australia having a small and erratic rainfall. Others have followed that lead, and today there are laboratories founded by the late Sir John Melrose, the John Darling family and the Ransom Mortlock family.

Under the leadership of the late Dr. A. E. V. Richardson from 1925 to 1938 the Waite Institute, as it is often known, was active in research on the water requirement of crops, crop rotation, fertiliser trials for cereals, mineral content of pastures, pasture establishment and management, wheat breeding, agricultural chemistry, soil research, entomology, plant pathology.

During that period and since 1938, under the leadership of Professor J. A. Prescott, the Waite Institute has achieved

an enviable international reputation. Within Australia it has been the active agricultural research agent for South Australia and has co-operated with the C.S.I.R. in many fields. Additionally, men have been trained there who have assumed leadership elsewhere. One phase of co-operation with C.S.I.R. is illustrated by the fact that since 1927 the Division of Biochemistry and General Nutrition has been able to maintain a field station at Glen Osmond and since 1929 the Division of Soils has had its headquarters there. Indeed for the formative years of the Division Professor Prescott was its Chief in addition to being Waite Professor of Agricultural Chemistry in the University of Adelaide.

The Development and Migration Commission

The Development and Migration Commission was established by Act of Parliament in 1926 under the Chairmanship of Mr. (now Sir Herbert) Gepp, with C. S. Nathon, J. Gunn and E. P. Fleming as members.

In its first report to Parliament the Commission pointed out *inter alia*—

> "In relation to primary production, the Commission must, by systematic research—in collaboration with the Council for Scientific and Industrial Research and appropriate state authorities—decide whether the soil and climate are suitable for the products proposed, whether there is an adequate rainfall or water supply, whether transport to market at reasonable charge is available, and, above all, whether there is a home market available for disposal of the products at a remunerative price and, if not, whether the commodity (having regard to the production of other countries) is of such a nature that a ready market can be found overseas.
>
> "Australia may be eminently suited in the matter of soil, climate, and other factors necessarily precedent to the production of a marketable commodity in large quantities, but it is of little avail to Australia, in a national sense, if the quantity be increased and the ultimate reward of industry, viz., disposal at a profit, is lacking. Indeed, the question of markets is, in the last resort, an all important one, and whilst access to a profitable market is the ultimate goal of the producer, the question whether such a goal can be vouchsafed for the new units of production proposed within any general scheme of development, is one of primary significance and is a condition precedent to the adoption of any scheme."

Among the industries considered were Dried Fruits, Canned Fruits, Fishing and Fish products, Dairy products, Tobacco, Cotton, Flax, Paper, etc., and in all of these co-operation was effected between the Commission, the C.S.I.R. and the various state departments directly concerned. It is interesting to note two references in the first report because of the fact that today there is a strong unit in the Commonwealth responsible for that work. Referring to Australia's relation to world conditions and markets, it says—

> "These phases of Australia's economic life have been referred to in order to stress the necessity for the most complete and thorough examination by way of economic research. It is the hope and intention of the Commission gradually to accumulate information with regard to economic facts and units of value so as to enable it to act as economic adviser to the Commonwealth and states on broad policies of development" and again, "Before proceeding to refer to migration the Commission ventures to mention the necessity for a study of economics and for the application of its principles to the practice of industry. Especially in primary production is a knowledge of world economics necessary."

The Council for Scientific and Industrial Research

Also in 1926 the Council for Scientific and Industrial Research was established by Act of Parliament, replacing the Institute of Science and Industry, which in time had arisen from the Advisory Council of Science and Industry. The late Sir George Julius as Chairman had with him on the Executive Committee Sir David Rivett and the late Dr. A. E. V. Richardson with Mr. G. Lightfoot as a very able Secretary. In the first years, 1927-1937, concentration of effort was on the problems of primary industry and so the Sections and Division had to deal with animal nutrition, animal health, pasture investigations, plant problems, entomology, irrigation, viticulture, soils, food preservation and transport, fisheries and the related problems of forest products.

The Prime Minister (Mr. S. M. Bruce) had stressed the need for co-operation with the states and one of the first steps taken by the Executive of C.S.I.R. was to call into conference on March 23 and 24, 1927, directors and under secretaries of agriculture of the six states together with certain of their senior technical officers and the professors of agriculture available at that time. From that conference emerged the proposal that the heads of the state departments of agriculture should constitute a Standing Committee on Agriculture for C.S.I.R. to meet twice a year to discuss primary industry problems and to advise C.S.I.R. what was best to be done. The first meeting of that standing committee was held in Adelaide, May 25, 1927, and one of the first matters discussed was tobacco production, when Mr. Gepp placed before the Committee the proposals initiated by the Development and Migration Commission.

The C.S.I.R. Standing Committee on Agriculture continued to meet until, in 1934, it was modified to become the Standing Committee on Agriculture to the Australian Council of Agriculture (first met May, 1935).

During the years prior to the 1939-45 war and despite the years of depression every effort was made to foster and do research work by C.S.I.R., the Waite Institute and state departments. There is no doubt about the decided strengthening of interest in research during that period nor is there doubt that co-operation gradually became more effective between those concerned. It is a pleasure to look back to many round table conferences between C.S.I.R. and state officers on technical problems. One cannot leave this period without mentioning the Imperial Agricultural Conference of 1927 and help given by the Empire Marketing Board in the furtherance of some of our investigations.

The strengthening of interest in research had its effect in university schools of agriculture and ultimately led to the increase in employment of scientifically trained officers in the departments of agriculture and in commonwealth departments. This development was fostered also by the devotion to research shown by members of the staffs of university faculties, some of whom have made notable contributions to science.

The Institute of Agriculture, Western Australia

In 1913, Sir Winthrop Hackett gave a sum of £18,000 to endow the Chair of Agriculture at the University of Western Australia. The first professor was appointed in 1914, but it was not until 1937 that Agriculture was separated from the Faculty of Science. In 1938, the Institute of Agriculture was founded when the School of Agriculture was given twenty-five acres of land at Crawley. A building was erected, partly financed by the University and partly by the State Government. A great deal of the work at this Institute has been directed towards pastoral problems and biological research in sheep, funds being provided in some instances by interested business firms. Emphasis has been placed as far as possible on the direction of recent gra-

duates in original work for higher degrees. The Institute works in collaboration with officers of the State Department of Agriculture and the C.S.I.R.O., and the presence of these officers provides a stimulus to those working there.

The Commonwealth Department of Commerce and Agriculture

The second World War following the depression years, made agricultural production for war purposes very difficult. Fortunately, the Standing Commitee and the Agricultural Council had by then some four years' experience of round table consideration of problems and were able to do what was so vitally necessary—look at problems from a national rather than a state point of view. It is interesting to recall at this stage that at the conference called by C.S.I.R. in March, 1927, the late Dr. S. S. Cameron, then Director of Agriculture in Victoria, said he felt that the time would come when a Federal Department of Agriculture would be formed, and was of the opinion that the time was ripe for it. If such a department was not initiated in Australia, then the three other nations of British origin, U.S.A., Canada and South Africa were all wrong. The war focussed attention on the need for concerted agricultural production, but despite its basic importance agriculture, from the federal point of view, is but part of the Department of Commerce—now designated Commerce and Agriculture. A most important development from the research aspect is the establishment of a strong unit for Agricultural Economics, now incorporated in the Department of Commerce and Agriculture.

The growing recognition of the dangers to food production and the stability of rural welfare by losses of good soil through water and/or wind erosion has, since the war, resulted in the establishment of authorities on soil conservation, similar to the establishment of irrigation authorities for water conservation in the earlier years. In this latter established field as with the former there is ample scope for research by all concerned.

The United Nations

The growth of Australia into nationhood carries with it responsibilities in the international field, not the least important of which are scientific. We are taking a fair part in aiding the solution of problems facing the Food and Agriculture Organization, U.N.E.S.C.O., W.H.O., and so on, and a leading part in connection with the problems of South-East Asia and the South Pacific.

All of these in one way or another are concerned with research on primary production and our experiments here are valuable in other lands.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN SOILS

By J. A. PRESCOTT

At the beginning of the century work on soils in Australia was in the hands of the State Departments of Agriculture and a number of appointments of agricultural chemists ensured some degree of stability. Amongst these were those of Howell to Victoria in 1899, Guthrie to New South Wales in 1892, and J. C. Brunnich to Queensland in 1897. One of the duties of the chemical services to which these men were attached was the examination of soils, and the records of the services show that a substantial amount of inco-ordinated information about the soils of Australia was being accumulated in this way. Guthrie, however, was very conscious of the incompleteness of information based solely on laboratory data from casual samples and he was an early advocate of soil surveys during which information with respect to soils could be obtained as completely as possible with respect to field occurrences and laboratory findings. Although formal soil surveys did not prove possible, in New South Wales the geological surveys of Jensen and the botanical work of Cambage were closely coordinated with Guthrie's interests and the information gathered in this way was made available in Jensen's book "The Soils of New South Wales" (1914). Jensen maintained his interest in soils and soil classification in his subsequent geological work in the Northern Territory and in Queensland and his records between 1914 and 1928 were a valuable source of information at a time when formal soil exploration in Australia was in its infancy.

Howell's duties in Victoria seem to have consisted primarily in the delivery of lectures to farmers and in the carrying out of field experiments. These experiments, together with those of Roseworthy College, started in a permanent form in 1904, laid the foundation for an appreciation of the importance of phosphate as the key deficiency in the soils of southern Australia. An important part of Howell's work (1911) included the laboratory examination of Victorian soils (both chemical and mechanical) and his findings were also published in book form.

Soil Surveys

B. Dunstan, the Queensland Government Geologist, had advocated a soil survey for Queensland as early as 1905. He suggested following the American practice and emphasised the need for the employment in this work only of men having had scientific training.

The next advocate of soil surveys in Australia was Guthrie (1907). At the Adelaide meeting of the Australasian Association for the Advancement of Science in that year he urged the need for such systematic work on soils. With the probable necessity of land settlement as a means of repatriating the men returning from service in the First World War of 1914-1918, the matter received further attention and a sub-committee of the Commonwealth Advisory Council of Science and Industry was appointed under the chairmanship of Professor R. D. Watt and this committee met and reported during 1916 and 1917. A further soil-survey committee of the Australian National Research Council was established in 1922 again under the chairmanship of Professor Watt. In view of the size and sparse settlement of Australia these committees realised that the most useful steps would

be to restrict the surveys to areas suitable for intensive exploitation and to collect and correlate the information already available in the State departments of agriculture, lands, forestry and geology. (In view of similar circumstances, soil surveys proposed after the Second World War were to have priority in those areas in which there was a substantial change in land use.) Probably the only formal soil survey which can be attributed to this early period is that of Kuitpo, South Australia, by Teale (1918). This area has formed a useful exercise ground for subsequent soil surveys conducted from Adelaide and is a type area for laterite in South Australia.

It is, however, only since 1927, that soil surveys have been developed systematically, in the first instance to meet the requirements of the irrigation areas of the Murray river and its tributaries. The impression of the twenties that the modern technique of soil survey was the only satisfactory approach to the problems of settlement in such areas has been abundantly confirmed during subsequent experience. In the first five years some 2,400 square miles of country were surveyed of which 1,100 square miles were in the wheat belt of Western Australia and surveyed by the agricultural and lands departments in that State. By 1950 the aggregate area of soil surveys in Australia was approaching a total of about 200,000 square miles, including detailed, broad scale and reconnaisance surveys.

The driving force behind the soil surveys was the need for a scientific basis to the problems of land classification. At the beginning of the century this was the responsibility of the survey sections of the state lands departments and was traditionally and correctly based on native vegetation particularly where marked contrast occurred as in the expanding wheat belt of Western Australia. The importance of native vegetation as an index of soil value finds its scientific extension in the ecological studies which have become a feature of the work of some of the University schools of botany. The Lands Departments still have a considerable responsibility in this regard and their responsibilities can best be exemplified by the recent activities of the Queensland Bureau of Investigation which, since 1944, has classified 37 million acres of land in that State in sufficient detail for Government action (Skerman, 1950). An important area covered was the "Channel country" in the south-west of Queensland, an area showing exceptionally interesting features.

Formal soil surveys in Australia began in 1927 with the appointment of J. K. Taylor by the newly established Council for Scientific and Industrial Research to the Waite Institute of the University of Adelaide as soil surveyor of the "Murray River Soils Investigations". The first unit to be examined was Block E, Renmark, and between 1927 and 1941, 22 irrigated horticultural settlements were surveyed in the Murray Valley extending from Murrabit in Victoria to Mypolonga in South Australia. In 1929, the Division of Soils was established by the C.S.I.R. in association with the Waite Institute and found adequate housing through the generosity of the family of the late Mr. John Darling. The Division of Soils is still the major soil survey organization in Australia, but throughout substantial areas have been dealt with by State Departments of Agriculture, notably those of Western Australia and Victoria, and by University schools of agriculture. The advances made in the ten years between the Pan Pacific Science Conferences of 1939 and 1949 have recently been summarised by Prescott and Taylor (1949) who give a full bibliographic guide to the activities during this period.

Pedology.

The soil survey, however, in addition to providing information of value to those responsible for agricultural development, forms a basis for those scientific studies

in which the soil is regarded as a natural object worthy of detailed attention for its own sake. Prescott (1927) had pointed out that for South Australian soils there was a marked general relationship between the reaction of South Australian soils, expressed as the pH value, and the average rainfall. The higher the rainfall the more acid the soils. This gave point to the Russian thesis that soils owed a great deal to the climate under which they were developed and that a broad zoning of soils could be expected in any continental area in which the influence of climate and geology on soil formation would be reflected. This broad zoning is observed in fact to occur and leads to the recognition of the so-called "Great Soil Groups". The adoption of the soil "profile" as the basis of description in the field and of classification on a broad scale proved its value in Australia as elsewhere and in 1931 Prescott produced a soil map of Australia which was revised in 1944. In the map of 1944 some 18 major soil groups were recognised, of which 5 belong to the desert formations. These maps were made possible in the absence of detailed surveys by taking advantage of every known and observed correlation between soils and geology, topography, climate and native vegetation so that full use could be made of the observations of the early explorers, pastoral inspectors, land surveyors, geologists and botanists.

Any further advance will depend on more systematic exploration and examination and proposals have recently been put forward for such a systematic approach. Stephens (1950) suggests the recognition of 36 great soil groups while Hallsworth and Costin (1950) recognise 39 such groups as occurring in Australia. The stage is set, therefore, for the preparation of a new map in which it is evident that there will be scope for many collaborators.

An important feature of recent work, exemplified by the work of Crocker (1946) and of Whitehouse (1940), is based on the recognition that many soils are the product not of current climate but of former climatic cycles and an extension of this type of work may well lead to a clearer understanding of the origin of many of our Australian soils.

Soil Chemistry

The correlation of the early chemical analyses with modern ones is made difficult by the changing fashions in such matters as the determination of "available" plant foods and by the marked increase in accuracy in analytical procedures over the past few years. Soil chemistry in Australia has naturally shared in all these international advances. Perhaps the most important concept introduced was that of pH values in the 1920's which has thrown important light on soil genesis as well as soil fertility. Of importance also has been the renewal of interest in exchangeable cations in the soil and the recognition of the importance of exchangeable sodium in determining the character of some of the great soil groups in Australia.

Perhaps the most characteristic Australian contribution to soil chemistry has been that relating to the factors determining the availability of plant nutrients in the soil starting with the work on manganese deficiency by Piper (1931) and Leeper (1934). Something is known also concerning factors governing the availability of molybdenum in the soil, less about copper and still less about zinc.

Of more recent interest is the endeavour to determine the forms of phosphate occurring in Australian soils (Williams, 1950) and this may well become more important in the future if the best use is to be made of the accumulated reserves in soils which have received regular supplies of superphosphate over a period of years. As more information becomes available regarding the amounts and forms of plant nutrients in the Australian great soil groups, the more it will become possible to take a broader view

and define the status of the soils in general geochemical terms. As the degree of leaching is important in determining the pH value or lime status of the soil, so may the number of cycles of weathering of the parent materials be found to play a part in determining the fertility level of the soils so derived.

One aspect of soil chemistry which has received attention since early in the century relates to the changes that take place in the nitrogen compounds in the soil during the course of the normal wheat rotation. The nitrate levels in bare fallows prepared for wheat and the associated soil moisture changes were first studied in Victorian soils by Paterson and Scott (1911) and have received periodical attention since. Low phosphate levels in Australian soils carry with them a low nitrogen status and current work centres principally on the rate of nitrogen accumulation in soils during the pioneer phases of development.

Soil Mineralogy

The mineral framework of the soil may be said to consist of a mixture of sand and clay. All sand consists predominantly of quartz but certain other minerals such as rutile, ilmenite and zircon are also recognised as being virtually indestructible. The identification of heavy minerals in the fine sand fraction of the soil may therefore serve as an index of the ultimate geological origin of a soil. This work has received most attention in Australia from Dorothy Carroll, starting in 1932.

The mineralogy of the clay fraction of Australian soils is becoming better understood with the introduction of the methods of X-ray crystallography and reference may be made to the early work of Shearer and Cole (1940). Both these aspects of soil mineralogy were pioneered in the University of Western Australia.

Soil Physics

Australia's earliest contribution to the study of soil physics was a notable one. In 1911 and 1912, Green and Ampt, of Melbourne University, published two important papers on the permeability of soil to air and water using both actual soils and graded beads and sands. They suggested as a result of their work that the measurement of permeability to air and water would be of more importance than, and should replace, analysis—that is that the properties of the pore space of the soil were of greater importance than the sizes of the soil particles. Provided the actual sizes of the particles are unaffected by water they considered it legitimate to regard a soil as statistically composed of a bundle of capillary tubes.

The study of soil permeability has become of increasing importance in the rationalisation of irrigation practice but with the emphasis on the whole profile as the soil unit, so that methods for study of permeability in the field have been perfected in more recent years and have proved of importance in assessing the irrigation properties of soils defined during surveys. Such studies have become a normal aspect of study at the irrigation research centres at Griffith and Merbein and by the Soil Physics section of the Division of Soils of the Commonwealth Scientific and Industrial Research Organization.

The importance of texture in soil description, however, makes the mechanical analysis of the soil of importance and the correlation between field estimates of texture and mechanical analysis has received considerable attention during the progress of soil surveys.

The most recent correlation is that of Marshall (1947) in which use is made of the modal value in the size distribution of the sand fraction of the soil together with the percentage of clay as the index of mechanical composition.

Of recent years increasing attention has been paid to soil structure both in the course of surveys and as a measure of soil deterioration under crop rotations.

The work of Downes and Leeper (1939) and of Clarke and Marshall (1947) may be mentioned in this connection.

A more recent feature of developments in soil physics has been the linking up with the work of the civil engineer in soil mechanics. The engineering properties of soils are of importance in road, airfield and building construction and in earth dams for the storage of water. Although not agricultural there is naturally a common link through soil physics and there is likely to develop an increasing mutual interest.

Soil Erosion

The recognition since the early thirties of the extent to which the soils of Australia were being wasted by erosion has influenced developments both in soil surveys and in soil physics. Of greater importance, however, is the recognition of the need for the development of a public conscience in this matter and of administrative and educational measures. All the states of Australia have established soil conservation authorities except Tasmania where the hazard is relatively small. For the purpose of ensuring coordination of policy and action among the States a Standing Committee on Soil Conservation was formed in 1946, consisting of the heads of the soil conservation bodies in the six States and three representatives of the Commonwealth. Soil Conservation has, in other words, become recognised as a current duty and an obligation to posterity.

Soil Microbiology

For many years soil microbiology was regarded by the Linnaean Society of New South Wales as a subject of appropriate interest for one of its Macleay Fellows. In 1898 R. Greig-Smith had been appointed Macleay Bacteriologist and among his numerous papers a series of 16 between 1910 and 1918 are entitled "Contributions to our knowledge of soil fertility". Greig-Smith's predominant interest at this period was in the effect of the so-called partial sterilising agents such as toluene and chloroform on bacterial numbers in soil. He explored the possibility of their effects as wax and toxin removers as opposed to the original theory of Russell and Hutchinson that their prime effect was due to a simplification of soil population and in particular the removal of protozoa. Greig-Smith held the fellowship until he died in 1927. He was eventually succeeded by H. L. Jensen who carried out a series of investigations on nitrogen fixation by soil micro-organisms.

One of the most important of the recent findings is the circumstantial evidence that molybdenum is essential for symbiotic nitrogen fixation in legumes (Jensen and Betty, 1943), Anderson, Thomas and Oertel (1946).

Over the years some considerable interest has been taken in the possible importance of *Azotobacter* in Australian soils. In the southern wheat belt there is little evidence of its importance but possibly in the black soil belt of Queensland it may prove to be more important.

The importance of legumes, particularly subterranean clover, in pioneering land of low fertility, has stimulated the study of the nitrogen fixing organism *Rhizobium* and of recent years there has been developed a considerably increased demand amongst farmers for cultures of appropriate strains of this organism.

Research into the effectiveness of these strains in relation to the host plant promises scope for much future activity.

Swaby's work (1950) on the bacterial factors responsible for soil structure is of current interest and provides a link with soil physics.

The Future Outlook

It can probably be truthfully said that in Soil Science this first half century of Australian Federation has paved the way

and opened up the vistas for progress in the near future—for only half this period has the Federal Government itself taken an interest in soil studies but these in themselves have stimulated activity in the States and the Universities. In pedology a great opportunity is afforded for the study of the polygenetic factors associated with former climatic and geological cycles. Soil chemistry needs to be linked with geochemistry, and soil physics and chemistry with microbiology.

The extension of soil surveys into the Australian tropics will doubtless also provide numerous stimuli for fundamental investigations in new fields of soil science.

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CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN PASTURES

By J. GRIFFITHS DAVIES

The story of pastures during the 50 years of Federation provides a fascinating pattern of development, yet it is a fact that practically every endemic plant that is being used for pasturage today was already known and described and that most of the naturalised and introduced plants now used were already here, though the potentialities of several important sown pasture species of today either were not known, or were realised by the few.

THE POSITION AT THE TURN OF THE CENTURY

(a) Endemic herbs and pasture plants

The golden age of the great naturalists was waning. Bentham, Robert Brown, von Mueller, Hooker, Betche, Turner, Bailey, Maiden and Rodway had practically completed the great task of classifying and cataloguing our native flora and had laid the foundation for economic studies. These men had gathered great knowledge of our important pasture plants. Today it is fashionable to scoff at the taxonomist as an unscientific being. I commend the scoffer to read the works of any of these great botanists—it is they who gave us our backbone of order from chaos. It is little use knowing some detail about the biochemistry of a plant unless one can at the same time determine what plant one is talking about. The science of genetics has since been developed and expanded but I doubt whether the modern botanist is any more aware of the complexity of our species and genera.

(b) Naturalised and introduced species

Most of our important grasses and legumes were being well exploited by 1900, though their present day production and distribution had not been attained. Perennial and Italian ryegrass; cocksfoot; prairie grass; lucerne; white, red and strawberry clover; *Paspalum dilatatum* and guinea grass were being used extensively and with a sound understanding of their climatic and soil requirements and management.

Lucerne

Lucerne was the most widely grown pasture and fodder crop in those days. J. L. Thompson (1895), Principal of Hawkesbury, describes the sowing and general management of lucerne both under irrigation and dry land, and advocates the application of 2 cwt. superphosphate, 1 cwt. kainit per acre and a top dressing of gypsum. This advocacy was based on its chemical composition as given by Sprengel and not on results of actual tests. However, he did show that a stand from "colonial saved seed from the Hunter district was almost a foot higher and yielded 100 per cent. more fodder in its second year than a stand from seed imported from England." This is the earliest reference to the importance of strain in Australian pasture plants that the author has seen and it is interesting to know that Hunter River lucerne was already recognised. There were extensive areas of lucerne under irrigation in both Victoria and New South Wales at this stage.

Prairie Grass

Prairie grass was a very important pioneer species on New South Wales coastal scrubs and was also used a great deal in Victoria and in Queensland. Italian ryegrass was similarly used. Chisholm (1897) wrote "I recall the days of the early eighties when small plots of Italian ryegrass and prairie were to be seen on the clearings in the Big Scrub. During the intervening years of drought and flood prairie grass held its own. It is the first (in the sense of best) of all succulent grasses that have been introduced to the North Coast of New South Wales." Cook (1897) wrote that on his property at Coraki he depastured cows at the rate of one per acre and they yielded 600 gallons per head of 3.5 to 3.8 per cent. butterfat. Not many pastures today can provide better results.

Paspalum

Paspalum dilatatum was introduced in Victoria by Baron von Mueller in 1881; he thought very highly of the grass and distributed seed widely. It found its best habitat on the North Coast of New South Wales by 1892. Morton Williams seems to have done a great deal to popularise it by advocacy and the collecting and disseminating of seed in the immediately following years. He wrote (1898) "I have concluded that *Paspalum dilatatum* is the very best grass for the farmer to rely on as a permanent pasture (for the North Coast). It is carrying a beast to the acre all the year round with me. Its qualities for dairying are undoubted and every cow is kept in good condition." It was being grown at the Wollongbar Experiment Farm before this date; Guthrie (1896) gives a chemical analysis of hay made from *P. dilatatum* at Wollongbar and compared it favourably for nitrogen content with an analysis of an unspecified hay made in England. McKeown (1896) describing the results of plot tests of 14 pasture legumes and 27 pasture grasses, concluded that *P. dilatatum* was the best grass and that Guinea grass was also a very valuable species. This report appears to be the first critical test of pasture plants in which yields were recorded.

Mahon (1901), Principal of the Queensland Agricultural College, introduced *P. dilatatum* to Queensland in 1896. He obtained his knowledge of the grass and material from Morton Williams. Mahon was an enthusiastic advocate of the grass at the time when the agriculturalists of Queensland were discussing the impact of the Commonwealth Act on the future of Queensland. He distributed "104,300 plants and a quantity of seed in 5 months" in 1903.

The enthusiasm for paspalum between 1892 and 1905 contrasts sharply with the rather "resigned" attitude of present day Australians to the grass, especially on the North Coast of New South Wales. There is, in my opinion, little doubt that the pioneer growers were getting better results than the farmer of today. This view was also held by Moodie (1940). Also it is clear that the swards were not completely dominated by paspalum, for the pioneer growers refer to its forming "the basis of the pasture and that other grasses and clovers are mixed with it." (Morton Williams, 1898.) Recent results by Arthur (personal communication) and Breakwell (personal communication) strongly indicate that the present-day dearth of clovers and the sod bound condition may be caused by trace element deficiency which could well have supervened after the effect of the clearing burns had been lost.

(c) Phosphate in 1900

Superphosphate was patented by Lawes in 1842 but it was not until about 1890 that its value to Australia began to be recognised. Custance made the first tests at Roseworthy in 1882 on wheat and by 1886 he wrote "I can strongly recommend superphosphate as the cheapest and best manure for the wheat crop. The quantity used should not exceed 3 cwt. per acre." Lowrie, his successor, con-

tinued his work and successfully urged farmers to use superphosphate. The phenomenal increase in the use of superphosphate in the South Australian wheat belt is given by Summers (1899) as from 60,000 acres phosphated in 1897 to 250,000 in 1898 and 400,000 in 1899. Howell (1902, 1903, 1904) from 1900 to 1904 proved that over a wide range of conditions in Victoria superphosphate gave increased yields of wheat, of hay, and of fodder crops. The results of Cockle Park experiments were certainly known but no trials on pastures were made in Australia before 1900. While the effect of superphosphate on wheat yield is considerable it is in some respects surprising that the enormous effects on pastures were not discovered earlier.

Pye (1902) considered that phosphates applied to crops could well have indirect benefits on the subsequent pasture. Lowrie (1891) wrote that it was of considerable importance to topdress pastures with, for example, bone-dust. He thought it would be better to use superphosphate, or some form that was readily soluble and readily available to the plant because of the relatively low rainfall in Australia. Guthrie (1894), discussing the manuring of grassland, stated that generally the proportion of clover was increased by potash and phosphoric acid and diminished by nitrogen.

Farmers were certainly using bone-dust on their pastures about that time. Mr. Mitchell (1900/1901), at a meeting of the Agricultural Bureau at Mt. Gambier in 1899, stated he intended to try bone-dust on grass to see whether it would pay. Mr. Wilson (1900/1901) said the result on light land would be very good and that in his experience bone-dust resulted in prolific growth of grass, of good colour and preferred by stock, and it also increased carrying capacity considerably on a pasture of Yorkshire fog and clovers.

The first references to tests of superphosphate on grassland are made by Summers (1902) in South Australia. Tests were to be made at Crystal Brook, Maitland, Riverton, Mt. Pleasant, Strathalbyn and Normanville. He also stated that a large landowner in the South East intended to manure 400 acres in that year. The results of these tests are given by Summers (1904). He found that pasture yields were doubled, the clovers stimulated, and at Aldinga, a remarkable residual effect of the phosphate was observed. He felt convinced that in a few years considerable areas of pasture land would be manured with superphosphate. Cherry (1907) was the first to study the effect of applying manures, including superphosphate, to grasslands in Victoria. Over 400 acres, in 5 acre plots, were treated in Gippsland, Southern, Western, Central and North Eastern districts with a view to increasing stock carrying capacity. The manures showing most favourable results were superphosphate and bone-dust. The great expansion in the use of superphosphate really coincided with the expansion of the use of subterranean clover related below, and it occurred between 1920 and 1930.

(d) Chemical composition of pastures

Guthrie (1896) gave the composition of paspalum hay from Wollongbar in 1896. The analysis of guinea grass was anonymously published in the Q'lnd. Agr. Journal in 1898 and later Ramsay (1899) published analysis of young and old shoots of Guinea grass. Brünnich (1901a, 1901b) appears to have been the first to make systematic chemical analysis of pasture species. He was fully aware of the rapid changes in the chemical composition with stage of growth and of the effect of nutrient status of the soils on the composition of the plant. It is interesting to find Brünnich drawing attention to low albumenoid ratio of paspalum grown at Gatton and on the Lockyer Creek in 1901 and contrasting it with Guthrie's much higher nitrogen figure at Wollongbar. It is clear, too, that the agricultural chemists felt they could judge the manur-

ial requirements of plants, including pasture plants, from their composition. The importance of the major constituents in supplying the grazing animal was also clearly realised and every analysis quoted the "albumenoid ratio." Soluble ash and total ash were measured but the ash constituents do not seem to have been separately assessed by our chemists.

THE DISCOVERY OF SUBTERRANEAN CLOVER

Without doubt the most important event (since 1900) was the "discovery" of subterranean clover by the Australian community at large. Here for the first time we have a plant of enormous agricultural importance, indeed vital to the present economy of southern Australia; developed from being an insignificant weed of the dry gravelly places and sandy foreshores of its native Mediterranean habitat to a pasture legume of first rate importance and eventually exported to other lands; New Zealand, South Africa and the United States finding a place for it. The strange thing is that the lands from which it originated still appear to have no use for it.

It is assumed that subterranean clover came to Australia from the Mediterranean countries but there is no real evidence whence it came nor when it came. It is of considerable interest to know that subterranean clover is recorded or was recorded almost everywhere along the coast of southern England and Wales from the Wash around to the banks of the Dee, with the exception of the chalk cliffs of Kent and Sussex. It was widespread in the Thames Valley, and the sandy heaths and village greens of London always carried subterranean clover. It was recorded in Hyde Park and Kew Gardens, it is still present at Hampton Court; around the coast near Deal and Rotherhithe and plentifully present near Southampton, Falmouth and on the Cornish coast and the Scilly Isles. The writer has specimens grown from seed recently collected by him at Hampton Court and at Aberystwyth. It is not impossible, therefore, that some of the subterranean clover today in Australia came from England and not from the Mediterranean. This is suggested by the presence of the plant near all the large ports of southern England which have served Australia.

Subterranean clover was recorded as naturalised in Victoria in 1887 (Audas, 1921). A. W. Howard noted it first in 1889 at Blakiston near Mt. Barker (Hill, 1936). Prescott (1950) states that von Mueller identified it for the Mt. Pleasant Agricultural Bureau, in South Australia, but whether this preceded Howard's finding is not stated. Maiden (1896) first recorded it in New South Wales in 1896, the plant having been sent to him by Mr. P. W. Lorimer who found it growing near the Wagga stockyards. Maiden's comment on the find, "It is not an introduction which need render us uncomfortable," is today a classic understatement.

Rowland Hill (1936) has given us the story of Howard's finding of the plant and of his long and eventually successful advocacy. Howard not only found subterranean clover in the agricultural sense but he was unquestionably the first to collect seed of it, to sow it and to apply phosphate to it. He was fully aware not only of its value as a grazing plant but of its value as a pasture legume in nitrogen fixation and in increasing soil fertility. It is rather astonishing to realise that it took a generation of advocacy before our departments of agriculture supported it and farmers generally became aware of its value. It is also quite clear that the primary development of subterranean clover was done entirely by farmers. At least there is no evidence that our agricultural scientists played any part in this development until the plant was very well on its way.

Farmers were, it seems, listening to Howard. Pye (1902) noted that *Medicago denticulata*, Strawberry clover, *Trifolium*

tomentosum, T. subterraneum and T. glomeratum were being frequently sent in for identification and found useful by farmers. M. Oberlander "tabled a fine specimen of *T. subterraneum* at the Millicent (S.A.) Bureau in November 1909. The other members present had not been fortunate with it. The heat of the summer seemed to kill the seed." (1909/1910.)

A number of tests of pasture species was made in Victoria, New South Wales and South Australia between 1900 and World War I, but in none of these was subterranean clover included. Yet, in 1910 the Victorian Department of Agriculture in its replies to correspondents was able to give the following information to three separate enquiries for identification and information (1910). "*T. subterraneum* is an introduction from the Mediterranean of some use as a pasture plant; it is also active in suppressing weeds. It takes 15-25 lb. of seed to sow an acre, but it is best used at the rate of 2-5 lb. per acre mixed with other grasses. It is an annual, but because it is a heavy seeder it can almost be regarded as a perennial. Once firmly established there is no occasion for further seeding. Seed is difficult to obtain."

An anonymous note in J. Agric Victoria (1918) records that subterranean clover grew in abundance on the volcanic soils near Flinders. The writer further stated that there were hundreds of acres of it, though to his knowledge, no paddocks had been solely sown to it.

Mullet (1922) was the first to officially recognise the plant as being a valuable pasture legume and to give advice as to how it should be used. He also pointed out that it could be readily established by merely drilling it across ordinary pasture land previously top dressed with superphosphate or preferably superphosphate and lime.

Spafford (1923/1924) gave a full review of the plant's capabilities, how to sow it, manage it, manure it and finally how to harvest the seed. He gave every recognition to the part played by Howard.

Cook (1922/1923) had sown a quarter acre plot of subterranean clover at Kybybolite in 1921 and by 1923 he was obviously enthusiastic about it (1923/1924). This appears to be the first plot sown at an experiment farm, though subterranean clover was clearly being used quite extensively by farmers in the south-east (Anon. 1922).

Rowland Hill (1936) records that quite appreciable amounts of subterranean clover seed were being harvested from 1916/17 onwards; in that year 5 cwt. of seed was collected in South Australia rising to 73 cwt. in 1919/20. However, it was not until 1923/24 that really substantial quantities of seed were harvested in South Australia, and more than 250 tons were harvested in the 1929/30 season.

WIMMERA RYEGRASS, PHALARIS TUBEROSA, RHODES GRASS AND KIKUYU

Wimmera Ryegrass

The story of Wimmera ryegrass is perhaps the oddest of all. Mullet (1919a, 1919b), first drew attention to the plant in his report on a farm competition in the Minyip district of Victoria in 1919. By this time, it was well established on many farms in the Wimmera and southern Mallee districts. Mullet found that the grass had been present on Mr. Light's property at Noradjuha for more than 32 years and that the previous occupier, Mr. McNicol, had brought it in from Europe prior to that. Again it is clear that farmers in the Wimmera were well apprised of its value for in both 1918 and 1919 over 2,000 bushels of seed were sold to seedsmen as Italian ryegrass. (Seedsmen later reversed the process and sold de-awned Italian ryegrass as Wimmera.) It was significant that Mullet was able to advocate using a mixture of Wimmera ryegrass, subterranean clover and King Is-

land melilot in 1919, yet it was not until 1922 that he wrote directly about subterranean clover.

Phalaris tuberosa

Phalaris tuberosa was introduced by the Toowoomba Botanic Gardens about 1884 (Ewart, 1908). It was one of over sixty species sent by the Department of Agriculture, New York, U.S.A., to Mr. Way, the Curator. His successor, Mr. R. Harding, found the grass growing vigorously on rubbish heaps and hedgerows at the gardens some years later, collected seed and distributed it. The name Harding grass used today in U.S.A. may be perpetuating his name in recognition of this work. After this initial distribution from Toowoomba (the precise date of which I have not been able to determine) specimens of the grass were shown at the Adelaide Show in 1906 (Cook, 1943/1944). In 1909 Grigg (1909/1910) thought the plant would prove valuable in the Meadows district of South Australia and he was proved correct nearly 30 years later by Trumble. In 1930 the main centre at which the plant was grown was the New England, in New South Wales; though there were one or two properties in Victoria and one property in South Australia on which the grass was being grown at this time (Trumble, 1930). Trumble's (1933) work at the Waite Institute really launched the grass into the important one that it is today and will eventually become.

Rhodes grass (*Chloris gayana*)

Rhodes grass was introduced from South Africa around the turn of the century. The first record of its being grown that the author has seen is J. W. King (1903/1904) who included it in a species test at Leongatha, Victoria, in October, 1902; but McKeown (1904), describing tests at Wagga Experiment Farm in 1903, states that he obtained seed of it from Dookie in 1901. Mr. Sylvester Browne, a grazier near Singleton, New South Wales, has been quoted as introducing the grass into Australia (Jones, 1911), and Musson (1908) recorded seed weight and germination of a seed sample received from Mr. Browne, who undoubtedly drew a good deal of attention to the grass.

The New South Wales Department of Agriculture offered Rhodes grass for trial by farmers in 1903 and Gorman (1905), after stating that Mr. Sylvester Browne was the first to bring it prominently forward, wrote that trials had been carried out for two years with plants grown from a small quantity of seed brought in from South Africa by Colonel Mackay. This places this introduction in 1902 or 1903.

The grass was very early taken to northern New South Wales and to Queensland, where, of course, it was quickly recognised as an outstanding contribution to our sub-tropical pastures. McPherson (1906) tested Rhodes grass at the Biggenden State Farm and argues in favour of "the expensive Rhodes grass as against Paspalum" because of higher yield and better winter production of the former. By 1911 Jones (*loc.cit.*) had tested it at Warren in central Queensland, Brooks (1912) wrote that "Rhodes grass is well known in many districts" and Purcell (1910), a farmer at Atherton, was convinced that Rhodes grass was a better plant for the tableland than Paspalum because it grew better in winter. Brooks (*loc.cit.*) wrote of extensive use of Rhodes grass on the Downs and confirmed McPherson's opinion of its frost resistance. By this time it was also recognised that the grass was peculiarly at home and valuable in scrub lands, i.e., on brigalow, bottle tree and rain forest scrubs in sub-coastal Queensland, but that it would not hold well on forest country, i.e., on eucalypt forests and savannah woodlands. This is equally recognised today and Rhodes grass pastures are regarded as practically permanent and mono-specific swards on the better scrub lands, whereas on the lower fertility soils of the eucalypt forests, except on the highest rainfall plateaus, Rhodes grass is

but sparingly used. An extraordinarily interesting fact about Rhodes grass is the preponderance of mono-specific swards. No other grass or legume is used or seems to survive in the pastures on good scrub lands. Pastures up to 45 years old have been examined by the author and they are still pure Rhodes grass. Christian and Shaw (1949) have quite recently combined lucerne with Rhodes grass on the black soil of the Lockyer Valley with marked beneficial effect both on the Rhodes grass and the steers grazing on the pastures.

Kikuyu Grass

Pennisetum clandestinum, Kikuyu grass, is becoming more widespread and favoured in eastern Australia, especially on the North Coast of New South Wales. The grass was introduced into New South Wales by Breakwell (1923) from the Belgian Congo in 1919. The original supply came from a single plant established at the Botanic Gardens, Sydney. It is unquestionably encroaching on *P. dilatatum* pastures in the Northern Rivers of New South Wales but whether this is desirable is still a matter of dispute. Its habit of growth makes it a most useful plant in soil erosion control, in binding creek and irrigation ditch banks, as well as being a strong competitor with bracken and blackberry. It has not received the attention it deserves in its best habitats in Australia. The Waite Institute has studied it at the limit of its climatic range and a method of seed production has been devised (1941/1942).

Other grasses

Other grasses of considerable value to specific areas of the Commonwealth that are in the earlier stages of development as sown pasture species and about which too little is yet known include: *Panicum antidotale* (Giant or Blue Panic); *Panicum maximum var. trichoglume* (Green Panic); *Melinis minutiflora* (Molasses grass); *Brachiara mutica* (Para grass). In the author's opinion *Panicum antidotale* is destined to play a most important role in our drier sub-tropical beef cattle areas. Its drought resistance is remarkable and its palatability very high, yet it will withstand in the most extraordinary way constant defoliation by both sheep and cattle.

A large number of attractive grasses and legumes has been introduced into Australia since 1919, especially by the C.S.I.R.O., Division of Plant Industry. The several state departments of agriculture have also been introducing many pasture and herbage plants and testing them. Some of these plants are undoubted acquisitions to our pasture potential more especially in our tropical and sub-tropical regions. Paltridge (1942) has shown how *Paspalum scrobiculatum* can be grown and managed successfully in the better rainfall areas of south-east Queensland. Miles' (1949) work in Queensland is also most significant pioneering in adding to our store of plants one day to be used in our pastures.

THE PERIOD BETWEEN THE TWO GREAT WARS, 1919-39

The end of the 1914-18 war saw a tremendous development of pastures in southern Australia, and especially in Victoria. Richardson (1924) reviewed the results of phosphatic fertiliser experiments in that State and showed that everywhere except in the Mallee areas superphosphate was the main fertiliser required for pastures. He calculated that Victorian pastures had lost through animal products taken away the equivalent of 2,000,000 tons of superphosphate since 1860. In 1925 Richardson became the first Director of the Waite Institute and immediately organised a team of research workers on mineral deficiencies of pastures. This led to tremendous advancement in our understanding of pastures and eventually to the realisation of the importance of elements other than phosphorus.

Subterranean clover and Wimmera ryegrass became well understood and exploited during these two decades. Bartels and his colleagues in Victoria did exceptionally valuable work on irrigated pastures, their management, watering techniques, mixtures to employ and their fertilising. By 1928 Bartels (1928) was able to provide detailed instruction on all these aspects.

This period, more especially between 1928 and 1935, saw the strains of the more important pasture species being studied with vigour. These studies were inspired by the original work of Stapledon and his colleagues at Aberystwyth and the work of Levy and his co-workers on ryegrass and white clover in New Zealand. Harrison (1932), in Victoria, did the most important work. His study of the local races of subterranean clover; of perennial ryegrass; of cocksfoot and white clover showed that valuable ecotypes of all these species were to be found in Australia. He found Bacchus Marsh and Tallarook sub-clover which are today most important strains, as well as a number of others which have not as yet been used to any extent. It was Harrison who gave us the concept of early flowering, mid-season and late flowering strains in subterranean clover. He followed this work to its logical conclusion and Victoria initiated seed certification of pasture species in Australia. This step was quickly followed by the other states, though the techniques used were not as rigorous. These schemes were of tremendous assistance in providing farmers and seeds merchants with appropriate strains for various purposes.

Nutrients other than phosphate

Samuel and Piper (1927/1928) recorded the first trace element deficiency in 1928, that of manganese causing "grey speck" disease in oats on the black soils near Mt. Gambier, South Australia. Zinc deficiency was first noted in the Wimmera on wheat and on subterranean clover, this following closely results obtained in Victoria with zinc on orchards along the Murray. Riceman and Anderson (1933/1934) discovered a double deficiency of copper and zinc on both pasture and cereals and considered that legumes seemed to be much more susceptible to both deficiencies than the grasses. Following further work by Riceman (1950), Anderson and Smith (1951), this discovery of the double deficiency has led to the recent developments of very poor country on Kangaroo Island and on the ninety mile "desert" in South Australia. Copper deficiency was also widespread in Western Australia where the "stalling" of subterranean clover over extensive areas of the south western Jarrah-Red Gum country is attributed to copper deficiency. (Teakle and Stewart 1939, and Teakle 1939, 1942).

Potash deficiency was recorded in 1932 by Twentyman (1938) in Victoria mainly in podzolic soils. This was shown to be fairly general where the pastures had been well improved with subterranean clover and phosphates both in the Western district and in Gippsland.

Anderson (1942, 1946) found that molybdenum deficiency was present on the lateritic podzols of the Mt. Lofty range in South Australia and that spectacular increases in the establishment and growth of subterranean clover pastures followed the use of 1 oz. per acre of molybdic trioxide in conjunction with superphosphate. Anderson (1948) also showed that this deficiency is present on the southern tablelands of New South Wales on both granitic and sedimentary podzols and that response to phosphate on these soils cannot be obtained unless molybdenum is supplied or lime applied to release this element from the soil.

Sulphur deficiency is the most recent finding. This deficiency has now been recorded on the basalts and granites of the southern (Anderson and Spencer, 1950) and northern (Roe and Hilder, personal communication) tablelands of New South Wales, and also near Kojonup in Western

Australia (Rossiter, personal communication). The black earths of the Darling Downs and the Lockyer Valley are also deficient in sulphur (Andrew, Barford and Kipps, personal communication).

An excess of manganese markedly reduces the production of lucerne in the Australian Capital Territory (Kipps, 1947) though this does not seem to prevent the satisfactory growth of subterranean clover on the same soil. A technique of preventing damage due to excess of manganese has not yet been devised, though increasing the pH with calcium is partially effective.

Endemic species and natural pastures

The natural pastures, composed primarily of the endemic species, have been recognised as the backbone of the cattle and sheep industry since the opening up of our interior lands in the forties and fifties of the last century. Attempts have been made to exploit these plants in sown pastures, but success has been extremely meagre. Valder (1896, 1897), Guthrie (1897) and later Breakwell (1923) studied the saltbushes as sown species in New South Wales. Pye (1902) described work he had done with *Danthonia* sp.; *Themeda australis; Stipa* sp. and *Dicanthium sericeum* and concluded that each of these species was of considerable value. Breakwell (*loc.cit*) throughout stresses the value of the endemic species.

From time to time attempts have been made to develop techniques for using these endemics but with the exception of small quantities of Mitchell grasses—mainly *Astrebla elymoides* and *Astrebla pectinata* and *Danthonia*—practically no success has been achieved.

In the better rainfall areas of southern Australia the natural pastures have been extensively top dressed with superphosphate, both with and without the "surface" seeding of subterranean clover. By skilful use of phopshate and judicious management it is possible to combine subterranean clover with a *Danthonia-Stipa* sward to form a productive and stable pasture. Phosphate alone usually results in marked development of annual legumes, *T. glomeratum; T. resupinatum, T. procumbens* and *T. arvense* being prominent. In New South Wales, the medics also are similarly stimulated in the native pastures, but yields and carrying capacity are not as high as from sown pastures (Cook, 1930/1931). Management of the native pastures has more recently been studied. Roe and Allen (personal communication) have studied Mitchell grass pastures in south-western Queensland and the Waite Institute has long-term studies on the grazing management of bluebush-saltbush stands in South Australia (Woodroffe, 1941).

Grazing management

The first studies on grazing management appear to be those on irrigated pastures (Richardson and Gallus, 1932, and Beruldsen and Morgan, 1936) in Victoria. Both concluded that a 4-6 weekly grazing cycle gave optimal results. In studies on a *Phalaris*, subterranean clover, lucerne pasture; Moore, Kipps and Barrie (1946) and Davies (1946) concluded that continuous grazing was equally effective under dry land conditions. Roe and Allen (1945) could find no benefit from winter and summer rotation as against all the year round grazing of a Mitchell grass pasture. Twentyman (1935) also found a system of rotational grazing of pastures in Victoria breaking down. In all these instances the tremendous growth of the pasture during the short "flush" period seems to completely outweigh any advantages theoretically derivable from intermittent rotational grazing. The botanical composition can, however, be modified by rotational grazing (Moore, Kipps and Barrie *loc.cit.*) Obviously this can have very important consequences.

Rotation of pastures with crops

The maintenance and improvement of crop yields and soil fertility, especially of organic matter and soil nitrogen, as well as of soil structure, demands the use of an appropriate pasture phase in the rotation. Crop rotation experiments in Australia have usually included a short and insignificant pasture phase, and in most instances the pasture phase has been treated as a crop and not grazed. This tends to follow the farm practice in which the duration of the pasture phase of the rotation scarcely ever exceeds one or two years. Economic considerations have tended to dictate this practice. However Hodgson (1939) at Glen Innes, New South Wales, in an excellent experiment, showed the value of red clover pasture in a rotation with maize.

More recently Penman (1949) and Bath (1949) at Rutherglen, and Forster (1950), have drawn attention to the use of subterranean clover pastures as a substantial grazing phase in rotation with winter cereal production. The conclusion that a rotation of 8-10 years pasture followed by a correspondingly long cereal phase is a finding of far-reaching importance. The annual medics and Wimmera ryegrass either alone or in combination are widely used as a stubble pasture; and the use of oats and barley as grazing crops on stubble is also a common practice in the wheat belt. One of the most interesting crop rotations is that of using three or four years of Wimmera ryegrass and subterranean clover pasture in rotation with rice growing on the Murrumbidgee Irrigation Area. This enables the rice grower to combine sheep and lamb fattening with rice growing, with markedly beneficial results on the yield of rice and with important reductions in the quantities of nitrogenous fertilisers needed for the rice crop.

The advancement in our knowledge of pastures achieved in the past fifty years has had profound and permanent effects on the soil fertility; on the range of crops grown and the numbers and kind of stock depastured. The fat lamb industry expanded partly because of improvements in technique of refrigeration, but without our vastly improved knowledge of pastures the industry would have remained relatively insignificant. In southern Australia the increase in sheep numbers that has occurred, the opening up of extensive tracts of podzolic, lateritic and coastal detrital soils has been made possible by advances in our knowledge of pasture plants and their nutrition.

Wheat growing has been increasingly thrust outward into the low rainfall areas, in part because of the rapid loss of soil fertility and soil structure resulting from continuous cereal cropping in our better rainfall areas. This was made possible by the breeding and selection of wheats increasingly capable of withstanding arid conditions. However, the wheat had to be retired from the extreme marginal areas because of uneconomic yields and disastrous erosion. Another consequence of taking our wheat into the more arid areas has been the increasingly poorer nitrogen content of the grain. It is clear that the nitrogen supply of the soil must place a limit on the nitrogen uptake by the wheat plant and the driving of wheat into the low rainfall areas has necessarily meant a lower nitrogen content. Wheat growing should now be taken back into the better rainfall areas where improved pastures have transformed the yield potential and the quality potential. The breeder should now concentrate on breeding wheat varieties that can utilise the high fertility following improved pastures. Longer rotations can then be introduced into the drier wheat belt of today and the marginal lands increasingly retired to pastures. The present moment is ideal to undertake this withdrawal of cereal growing from the outer wheat belts because of the favourable sheep and wool prices.

THE FUTURE

The major problems awaiting solution lie in our summer rainfall areas, and the

growing of improved pastures in these sub-tropical and tropical regions is the only basis upon which Australia can expect to use the huge tracts of undeveloped and partially developed lands. The beef cattle of Queensland generally eke out a precarious existence on the natural pastures. These are almost solely gramineous and of exceedingly low nutritive value for the greater part of the year. The greater proportion of the soils are derived from granites and poor sedimentaries while there are substantial areas of coastal sands of extremely low fertility.

The growing of better pastures in these summer rainfall areas demands a new approach by the agricultural scientist. The testing of better grasses and the search for legumes must be inseparably linked with the definition of soil nutrient deficiency over a wide range of soil conditions. The dearth of pasture legumes in our coastal and sub-coastal areas of New South Wales and Queensland is unquestionably the result of soil nutrient deficiencies and not climatic. It is vain to attempt to introduce pastures demanding high soil fertility, pastures that will provide stock with a diet adequate in quantity and nutritive value, unless the complex of major and trace element deficiencies certainly existing in these areas are elucidated and corrected.

Wheat and cereal growing should be increasingly directed to our better rainfall areas and combined there with "ley farming," sheep and even dairying. This involves two consequences: the wheat breeder must re-orientate his breeding policy to make wheat varieties that will utilise the higher nitrogen and general fertility status and also withstand the more constant and extensive disease attack that will be experienced. If Australia is to have enough bread and butter to feed a much higher level of population this approach appears to be imperative.

The more arid areas now growing wheat should be retired to pastures, and a much longer rotation adopted with pastures and sheep grazing in the wheat belt generally. This involves more intensive research into pastures for lands receiving less than 18 in. to 20 in. per year and with a short influential rainfall season. There is a number of species already available which can be exploited including the annual medics, lucerne, Wimmera ryegrass, Mediterranean grass, veldt grass and evening primrose. This range of plants is inadequate. The geneticist and plant breeder must turn his attention to our present complement of species, the plant introduction specialist must import new gene complements for these species that we know, as well as search for new species yet untried.

The main untapped reserve of plants, however, was here long before we arrived —the endemic species. Our effort to exploit our endemic species has been sadly disjointed and the more spectacular and immediate benefits accruing from the exploitation and building up of our introduced species has been allowed to reduce our efforts with the natives almost to vanishing point. This follows the present-day tendency to demand quick results. There are scores of endemic grasses in the genera *Danthonia, Stipa, Themeda, Dicanthium, Eragrostis, Panicum, Eriochloa, Paspalidium, Chloris* and other genera which deserve close study with a view to selecting ecotypes capable of being used as sown species. The major technical difficulties associated with seed production have been solved for us by the Nursery Division of the Soil Conservation Service of the U.S.A. A long-term programme of study of the agrostological status, drought resistance, survival under grazing, methods of seed production and harvesting, establishment and climatic adaptability of our native grasses, herbs and shrubs should be instituted. It is within this rich store of species and gene complexes that we can hope to find plants that will rehabilitate the worn-out grazing lands of our arid areas and enable us to retire our marginal areas from

wheat growing and to re-vegetate them. It is the endemic species that will give us the plants to provide longer rotations in our cereal growing areas and not introduced plants presently here or to be obtained in the future.

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CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN CROPS — I. CEREALS

By S. L. MACINDOE

Historical Background

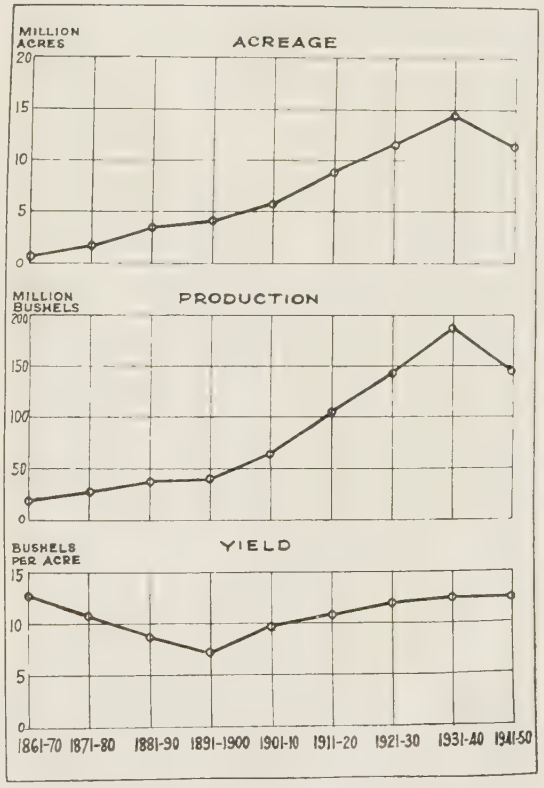
The early history of the Australian continent is largely the history of its agriculture. Struggles to feed a penal settlement gave way to the difficulties associated with the opening up of vast tracts of grazing country, the products from which were required to pay for the importation of those manufactured articles on which a reasonable living standard and the further development of the country largely depended.

Increasing population created the demand for more foodstuffs of which the cereals, especially wheat, were the most important. Yet yields of these were low, especially when grown away from the coast. Economic means of land preparation and especially of harvesting wheat were therefore of the utmost importance. The invention by an Australian farmer, J. Ridley, in 1843 of the "stripper" for harvesting wheat was an important factor in the gradual expansion of wheat production during the last fifty years of the century. The use of the stump jump plough, introduced by the South Australian farmer, R. B. Smith, in 1876, allowed early cropping of land only partly cleared of stumps.

INCREASING EFFICIENCY OF WHEAT PRODUCTION

A comparison of graphs of average Australian wheat acreage, production and yield in ten year periods commencing 1891-1900 indicates that during the first forty years of federation there was a steady increase in acreage, total production and yield per acre, which was initiated during the ten year period prior to federation. The fact that it did not extend into the ten year period 1941-50 was due primarily to restricted production brought about by war conditions and in the case of yields, by war induced superphosphate and material shortages and by two acute drought years experienced over most of the wheat belt.

The remarkable fact is that production and yield were not only sustained, but actually increased during the period of expansion of wheat growing into areas of



Average Wheat Acreage, Production and Yield in Australia.

Adapted from Current Affairs Bulletin, January 31, 1949.

lower rainfall and in spite of soil exploitation due to too frequent cropping. This suggests that technical progress offset factors which might otherwise have been expected to lower yields.

Perhaps more important still has been the influence of technical developments in increasing output per man. It is probable that during the past fifty years acreage and production per man have more than doubled in the case of wheat. The acreage of wheat grown annually on a typical family farm has increased from perhaps 100 to 300 acres. Crawford (1947) has estimated that whereas numbers engaged in Australian farming increased by 22 per cent. from 1911 to 1933, farm output increased by 50 per cent. in the same period.

The main factors responsible for this increase in efficiency of production in the case of cereal crops especially wheat will be dealt with under three headings—improved machinery, sounder cultural practices, and better varieties. The degree to which planned research has contributed toward improvements varies, progress in many instances being due to engineers or farmers working in co-operation with research or extension personnel. Some of the most important contributions made by planned research have been in the establishment of the principles underlying farm practices which have proved successful: this has permitted the efficient extension of innovations to districts and environments very different from those in which they were originally developed.

Improved Machines increase Acreages and Yields

The Development of Harvesters

Ridley's stripper was a considerable improvement on harvesting with the sickle or cradle. Although up to 10 acres per day could be stripped with it, it was still necessary to store and laboriously winnow the grain and chaff making use of the wind or hand winnowers. This was a tedious and exhausting operation in the heat of the Australian summer and when delayed it interfered with soil preparation for the succeeding crop. Only with the general introduction of the combined harvester which separated the threshed grain from the chaff was it possible to greatly increase output per man. While this machine was introduced by H. V. McKay in 1884 it was not until the turn of the century that it came into general use. It is significant that this coincided with Australia's entry into world wheat markets, exports in 1901 being worth £3,000,000.

The use by farmers some 12 to 15 years later of the reaper thresher added still further to efficiency of production, many damaged crops being harvested which would otherwise have been partially or completely lost. A modern eight-foot tractor-drawn header harvests and cleans 15-20 acres per day while a 14-foot power take-off machine may harvest twice that area.

Combine Seed Drills

The introduction of the seed drill, of which there were only 849 in Australia in 1902, made it possible for large areas to be sown more rapidly and efficiently. At that time only a small proportion of such drills allowed superphosphate to be sown in close proximity to the grain, a procedure which greatly increased the response obtained. The use of these drills was to increase rapidly during the next two decades during which the majority of farmers came to use superphosphate at seeding. During the last twenty years the general use of the "combine" which cultivates, sows and fertilises in one operation has reduced cultivation costs.

Tractors

As early as 1920 a few tractors of doubtful reliability were in use on wheat farms but by 1943 about half the wheat farmers used tractors. Shortage of manpower during and after the war, coupled with high wheat prices have now made tractor power general throughout the wheat belt. This has in-

creased acreage handled per man and has in some areas improved cultivation practices and reduced harvesting losses. In northern districts of New South Wales where wheat is grown after wheat for many years in succession without apparent loss of fertility, tractors have expedited harvesting and early preparation of the ground for the next year's crop. This has substantially increased yields. The general change over from steel wheels to pneumatic tyred wheels has increased efficiency of operation of farm tractors as have also the crawler type tractors under certain conditions.

Disc Implements

The use of discs set back at the top to provide a self-entering angle to the cutting edge is claimed by Vasey (1950) to be an Australia invention, as is also the twin disc cultivator. The wide use of such disc tillage implements has cheapened production because they require less draft than the moulboard. Rigid tyne or "Wimmera" scarifiers have been of value in weed control and the preparation of compact seedbeds. More recently they have been used in some areas even for the initial working of the land.

Rotary Hoes

An Australian designed rotary implement with a heavy type of cutting hoe has been successfully used for 25 years on coastal farms. It has recently been enlarged to a 9 ft. cut and redesigned so as to trail behind the tractor and to operate at higher forward speeds and at lower rotar speed. Reduced rotar speed lessens pulverisation of the soil and leaves a higher proportion of straw on the surface of the soil. Because of its ability to handle large quantities of straw and weed growth even when the soil is damp, it is probable that this type of machine will find a place on the most modern wheat farms of the future, especially if used in conjunction with a projected seeder capable of dropping the seed on to the firm seedbed below the mixture of soil and trash thrown up by the hoe blades.

Another implement likely to be of value in the trend towards trash or stubble mulch farming is the Trash Culti-seeder which is capable of cultivating and seeding even when an appreciable amount of straw is present.

Motor Transport and Bulk Handling

The replacement of horse drawn transport by motor vehicles has expedited harvesting and increased two or three fold the distance from rail where wheat can be grown profitably. In view of the likely reduction in jute supplies it is anticipated that the present general practice in most States of handling wheat in bags from the paddock to siding will be replaced largely by bulk handling with or without a period of farm storage.

It appears possible that in the future trained agricultural engineers attached to Departments of Agriculture or Universities will play a bigger part in supplementing the engineering knowledge of machinery firms.

Cultural Practices Improved

The Importance of Superphosphate

As is perhaps to be expected, scientists have played a more direct role in the introduction of improved cultural practices than in the evolution of better machines. Watt (1950) has traced the contributions of Professor Lowrie of South Australia in demonstrating at the end of the last century that it was profitable when sowing wheat to place with the seed, superphosphate at the rate of 1 to 2 cwt. per acre. Lowrie found at Roseworthy a seven bushel increase from an application of 1 cwt. per acre of superphosphate.

Early in the century the use of superphosphate was becoming general amongst progressive wheat growers. The first available figures for importation of rock phosphate are 306,592 cwt. for 1905. Within three years this had climbed to over a million cwt., by 1920-21 to over 4 million cwt. and by 1928-29 to over 12

million cwt. Depression years and war had a noticeable effect in reducing imports but it is estimated that a record is likely to be made in 1949-50 with the importation of 23 million cwt., slightly more than half of which will have been used for manufacture of superphosphate for wheat.

As the result of hundreds of trials conducted at research institutions and in cooperation with farmers, the amounts of superphosphate which it is profitable to use in particular regions have been determined. There is, however, some evidence that the frequent application of superphosphate over a number of years is resulting in an accumulation of phosphate in soils previously deficient. If wasteful use of superphosphate is to be avoided further investigations are required to determine desirable rates of application in relation to particular methods of land use. The possibility of replacing part at least of the superphosphate by finely ground rock phosphate is being investigated because of a possible shortage of sulphur used in the manufacture of superphosphate. The relative benefits of applying fertiliser to the pasture preceding a cropping phase rather than to the wheat crop itself also require further study.

Fallowing

The advantages of the long or cultivated fallow were known earlier, but Professor Lowrie was largely responsible for its general adoption in South Australia where, combined with the use of superphosphate, it is claimed that it resulted in the doubling of average yields. Sixty per cent. of wheat crops are now grown on a 6-9 months' fallow, but there are indications that this proportion is declining due partly to withdrawal of some marginal lands from farming and also to the adoption of practices designed to reduce erosion and maintain a more permanent soil fertility.

Shallower ploughing and the use of scarifiers were fallowing practices which were demonstrated to be desirable in many areas, and they have become general over the past two or three decades.

Ley Farming

During this period too increased attention has been given to the sowing of pasture leys which may be retained for one or more years in the case of Wimmera rye and subterranean clover, to as much as five or six years in the case of lucerne or pasture mixtures containing lucerne or other perennial pasture mixtures. In the higher rainfall areas the clover pasture mixture is most frequently sown with the wheat crop. Superphosphate topdressing of such pastures has been found to improve them greatly in most southern wheat areas. There is also a marked trend towards the ploughing under of such pasture as late as January or February prior to the sowing of the wheat crop in April to June.

The successful sowing of wheat-belt upland grazing lucerne at seeding rates as low as 2-3 lbs. per acre was the direct result of trials conducted in New South Wales in 1920. In the case of the early use of Wimmera rye in Victoria and subterranean clover in South Australia, individual farmers appear to have given a lead which was soon adopted by extension officers. In parts of South Australia field peas too have been shown to be effective in maintaining soil fertility.

Systems of ley farming are still only being used by a minority of progressive wheat farmers. There is urgent need for many more rotation or land-use trials to determine the best methods of economically maintaining soil fertility and improving the numbers and health of stock carried.

In this connection too there is a need for other soil building pasture species especially for those areas where the growth of subterranean clover is unreliable. For this purpose a large collection of medics is being carefully investigated and it appears likely that some of the burrless or slightly burred medics under trial might, during the next decade, ex-

tend into areas where species which build up soil nitrogen are lacking or present only in the form of the burr medic.

Control of Weeds

One weed of great importance in parts of the wheat belt is the deep rooting perennial Skeleton Weed. Trials have shown that Skeleton Weed does not invade areas where grazing lucerne is sown. Skeleton Weed infestation is claimed also to have been largely reduced by sowing grazing lucerne. However, it is difficult to establish lucerne in areas heavily infested with Skeleton Weed and it is in any event unlikely that farmers can be prevailed upon to sow the millions of acres of lucerne which would now be needed to reduce the density of the weed over the vast areas of country on which it is growing. Yet because of its pasture value to sheep, especially in a dry summer and also in view of the likely effect on soil structure of such a perennial pasture species, Skeleton Weed would be an asset providing a satisfactory wheat crop could be raised on infested land every three or four years. There are already indications that low volume hormone sprays at a cost of less than £1 per acre may be used on the wheat crop in the early stages of growth to so suppress the weed as to allow the harvesting of a profitable grain crop. Further research may indicate that even a partial control along these lines may result in a very desirable system of farming on some wheat country, at least while sheep are as important as cash crops.

Hormone sprays are not yet being extensively used to control weeds in the wheat belt but in parts of Victoria it appears probable that the use of small quantities of 2,4-D on the growing crop will be used as standard practice for control of cruciferous weeds in cereal crops.

Crop Rotations, Soil Fertility and Erosion

There is experimental evidence of the loss of soil structure and of the lowering of soil nitrogen as the result of continuous wheat cropping of some wheat soils. Unfortunately insufficient is known of the fertility trend of most wheat soils.

From the studies of Cornish (1949) it appears that in the South Australian wheat belt yields on some soils are declining due to depletion of nitrogen after 20-40 years of cropping, on others they have actually increased and on intermediate types there is yet no apparent change. The fact that record yields are still obtained in favourable seasons from the better loams, even after they have been farmed for half a century, suggests that with reasonable attention to the principles of good husbandry declining fertility is not inevitable.

In spite of many early warnings it is perhaps natural that during a period of expanding agriculture excessive clearing of steep slopes, overcropping and overgrazing and the extension of cultivation into semi-arid regions should have resulted in widespread erosion by water and wind. By 1938 the seriousness of this problem led to the establishment of a separate Soil Conservation Service in New South Wales. Early investigations suggested that accelerated erosion was evident to greater or lesser extent over more than 50 per cent. of that State.

All States now have either independent soil conservation organizations or a special branch attached to the State Department of Agriculture. By advice to landholders, the laying out of conservation works and the hire of special earth moving plant it is felt that some of the greater hazards of erosion in cropped land have been brought within reach of control.

Present emphasis is on the adoption of wider rotations with wheat grown not more frequently than one year in three or four, a reduction in the length of the fallowing period, the greater use of pastures and stock and the non-burning of stubbles.

Improved Varieties fill the needs of an expanding Wheat Belt

Breeding for Disease Resistance and Higher Yielding Varieties

The claim has frequently been made that without the breeding of wheat varieties

suited to the Australian environment it would have been impossible for this country to become a major wheat exporting country. This is perhaps no exaggeration but it is also true that without machines, superphosphate and the adoption of dry farming methods, the conditions could scarcely have existed which called for the release of the high yielding, early maturing, strong strawed variety Federation. It is of particular interest to note that this variety was named and released by Farrer in the year of federation now being celebrated.

Farrer's first concern when he commenced wheat breeding on his private farm in 1886 was the production of stem rust resistant wheats. This objective was never realised but his earlier maturing wheats tended to escape damage from rust more frequently than the Lammas and Purple Straw varieties then grown. In Federation he achieved a combination of the earliness of the Indian wheat with the yield of the Purple Straw. Though little of the quality of the Fife parent was retained in Federation the extension of the wheat belt into drier areas made possible by this variety did help to raise the protein content of Australian wheat. By 1910 Federation had become the leading wheat in Australia, a position which it still retained in 1925. Indeed, Federation eclipsed all Farrer's other varieties including Bobs, Cleveland and Florence, which at various times occupied areas of some importance.

The production by R. Marshall of South Australia of Marshall's No. 3 and of Yandilla King added two high yielding but later maturing wheats for sowing earlier in the autumn than Federation. Gordon and Pye in Victoria, Soutter in Queensland and Pridham in New South Wales each contributed high yielding wheats of real value to the farmers in their own States.

During the late 1920's flag smut threatened wheat production in a number of areas. Although its presence was known before the end of the century, heavy infections of this soil borne disease were favoured by the earlier sowings recommended in the interests of high yield. In the presence of susceptible varieties there appeared to be no limits to the havoc which could be wrought by flag smut over large areas of the wheat belt. In the search for resistant varieties it is fortunate indeed that Sutton had earlier selected Nabawa, which because of its yield and flag smut resistance became the leading wheat in Australia by 1935. Amongst other high yielding varieties found to have moderate to high flag smut resistance were Ghurka, Ford and Dundee. Bencubbin, which resembles in morphological characters and flag smut resistance the Nabawa parent it has replaced, is now the leading variety and occupies about one quarter of the Australian wheat acreage.

The rapid swing over to such resistant varieties has virtually eliminated losses from flag smut, while Darnell-Smith's discovery of bunt control by the easy method of using copper carbonate dusting of the seed has proved almost equally effective in reducing losses from this disease too.

Unfortunately the problem of breeding rust resistant varieties has not been solved so effectively. Australian wheat breeders have probably been more unfortunate than those in any other part of the world in breeding highly stem rust resistant varieties which within a few years have become completely susceptible on account of the appearance of new races of the rust fungus. A resistant Thew x Canberra hybrid bred by Waterhouse became susceptible to a new race of rust in 1929. Of the three stem rust resistant varieties released about 1938 only Eureka was grown on large areas, mainly in northern New South Wales. But again the appearance of a new strain of stem rust in 1942 rendered it quite susceptible. Other resistant varieties, including Gabo and Kendee bred at Sydney University and Yalta and Charter released by the N.S.W. Department of Agriculture, lost most or all of their resistance to a new rust race in 1949. Gabo

and Charter still have a moderate resistance but the more highly resistant Celebration and Warigo are not likely to become dominant varieties, although Warigo was second in popularity in South Australia in 1948-49.

Pugsley successfully used the backcross method to add the stem rust resistance of Gabo to most important Australian varieties. This programme was frustrated temporarily when the resistant parent and hybrids became susceptible to the new race in 1949.

Thus on three occasions soundly based breeding programmes have been successful in the production of desirable varieties only to be upset by the sudden appearance of new races of the rust fungus. These programmes of breeding for rust resistance have been based on the introduction of resistant parents from Kenya Colony, Egypt and the United States of America.

Baking Quality

The task of combining high yield and high baking quality in a single variety was pioneered without much practical success by Farrer. Later breeders achieved little real progress until the late 1930's when Fedweb and Eureka produced quite high yields of good quality grain in northern New South Wales. The fairly wide cultivation of Gabo, Charter, Kendee, Yalta and Celebration has recently increased the proportion of medium or strong wheats grown in New South Wales to about one third of the total. In South Australia some quality improvement has been made by Breakwell's varieties Scimitar, Javelin and Dirk and the inroads of the undesirable Quadrat have been opposed. In Victoria the somewhat better quality Pinnacle and Diadem have during the past year or two increased at the expense of the dominant Quadrat.

BETTER OAT VARIETIES EXTEND USEFULNESS OF THIS CROP

When Pridham first expressed to Farrer his desire to commence the improvement of oat varieties by breeding, Farrer warned him that it would be a difficult task in view of the excellence of the variety Algerian. This proved true and Algerian is still the leading late maturing oat for cool and moist districts. However Algerian is quite unsuitable for some of the drier parts of the wheat belt if hay or grain is desired. It does not fit well into farming operations even in better rainfall areas where farmers prefer to sow oats for grain or hay after the main wheat plantings are completed and also to complete the oaten hay harvest prior to the wheat grain harvest. Further, oats are largely in demand for early grazing or for green feed.

Pridham realised that earlier maturing oats would fill the demand for all these purposes better than the longer season Algerian. About 1912 he selected the earlier maturing Sunrise from Algerian and subsequent selection therefrom gave rise to Belar and Mulga. Later as the result of crossbreeding he released such varieties as Guyra, Lampton, Lachlan and Weston. These varieties have had an important bearing on the increase in Australian oat acreages from an average of 406,736 acres for the five year period of 1896-1900 to 1,860,000 acres during 1946-50.

Further progress in breeding improved oat varieties has been unjustifiably slow. The introduction about 1930 from the United States of America of Fulghum made available a variety which, while it provided early grazing and a good recovery, possessed such undesirable agronomic characters that it was of more value as a parent for breeding work than for farming. Unfortunately, its early resistance to smut disappeared with the occurrence of a new race of smut in 1936. However the locally bred varieties Belar, Guyra, Sunrise and Mulga have all been found to have a satisfactory field resistance to smut.

In recent years Dale and Ballidu bred in Western Australia have been found as

useful in certain areas. In Victoria, Algerian has now been largely replaced by the selection from it named Algeribee. The changes in the stem rust and oat smut fungi which have delayed breeding programmes, do not excuse the slowness with which the characters of excellent resistant parents have been combined into commercial varieties. Klein 69B and Berger, two Crown Rust resistant oats introduced from Argentina are likely to find a direct usefulness in at least the more humid parts of Queensland and New South Wales where leaf rust is of considerable importance especially in grazing oats.

In the case of smuts, some progress has also been made in the past decade in the wide use of fungicidal dusts which give a measure of control.

RESTRICTED PROGRESS IN BARLEY IMPROVEMENT

During the whole of this century Pryor has continued to be the dominant malting barley but the variety Research, bred in Victoria, has in recent years replaced most of the Archer type barleys previously grown in southern Victoria and the south-eastern part of South Australia.

HYBRID MAIZE RAISES YIELDS BUT MECHANISATION IS BACKWARD

Of all the major field crops maize alone has shown a decrease in acreage since the end of the last century, i.e. from an average of 326,000 acres in 1896-1900 to 219,000 acres in 1946-1950. During this period the regions in which maize is grown have not expanded appreciably as is the case with wheat or oats, and coastal maize areas have become more diversified with grain crops second in importance to dairying. Under such conditions maize paddocks are small, and mechanisation has been unimportant and backward, at least when farm labour problems were not as acute as at present. During the past decade larger scale drills, cultivators and harvesting machinery have come into use mostly in some tableland areas. In addition to the recent introduction of a number of American corn pickers, Davy and Sons of Copmanhurst have designed the Maize Queen corn picker intended especially for the heavy late maturing coastal maize crops. On the tablelands of New South Wales there appears to be a future for the Warwick machine which delivers shelled grain into bags. It appears probable that any future expansion of maize production is likely to be in tableland areas where the pattern of farming and climate favours larger scale production and the use of harvesting machines.

Since the mid-twenties plant breeders in New South Wales and Queensland have been actively engaged in successful programmes of hybrid maize. More recently the Shand Selected Seed Company has also been producing hybrids built up from American inbreds. In New South Wales approximately half the maize acreage is already sown to hybrid maize and there is ample evidence that the approaching replacement of existing varieties by hybrids should lead to an increase of 15 to 20 per cent. in present Commonwealth maize production. The better standing qualities and disease resistance of hybrids will be a further aid to mechanical harvesting.

The introduction during the past few years of hybrid sweet corn from inbreds of American origin is also raising the quality, yield and popularity of this crop. A similar programme has been commenced in the case of pop corn.

INTRODUCTION OF DWARF SORGHUMS STIMULATED PRODUCTION

The introduction from United States of America into Queensland and thence into New South Wales of the dwarf types of grain sorghum suitable for "header" harvesting, led to a rapid expansion of wartime and immediate post-war production of this crop.

Grain sorghum acreage increased from 4,000 acres pre World War II to a maximum of 140,000 acres in 1947-48. The following year saw the commencement of the sorghum growing project of the British Food Corporation at Peak Downs when 29,000 acres were sown to this crop. In 1949-50 this increased to 66,000 acres which together with the 102,000 otherwise raised, resulted in a total acreage in excess of the previous maximum.

Wartime and post-war need for increased feed grains coupled with the failure of many wheat crops in the drought years of 1944-45 and 1946-47 were important factors leading to this phenomenal expansion of production. This necessitated the conduct of numerous cultural and variety trials in summer rainfall areas. Even on the Murrumbidgee Irrigation Area numerous trials have returned yields of over 100 bushels per acre under irrigation but there is at present no appreciable extension of production in this area.

Dwarf Milo, the original introduction, has been replaced by still better introduced varieties, notably Caprock and Plainsman. Investigations are also in progress on the growing of the variety Cody which produces a waxy flour sought after for the manufacture of adhesives.

LINSEED AND FLAX

Linseed and flax are varieties of the one crop plant, the former grown because of the value of the seed for oil extraction and the latter because of the value of the stem fibres.

As the result of a wartime drive to increase flax fibre production a normal pre-war acreage of about 2,000 acres was rapidly increased to a maximum of 61,000 acres in 1944-45. This has declined subsequently to 8,000 in 1949-50.

Rapid wartime expansion created numerous problems both technical and administrative which it was the function of the Flax Production Committee to solve. The Committee which worked largely through Commonwealth and State Technical Officers, was responsible for the introduction and large scale testing of a wide collection of varieties, the best of which was distributed. Numerous cultural aspects were investigated and machines introduced and modified to meet local conditions. Technical information on growing and harvesting of crops was made use of immediately because of the control exercised in the industry.

War and post-war shortages of linseed with resulting high prices necessitated an intensification of earlier attempts to grow linseed commercially in Australia. From a pre-war average acreage of only 10 acres and from 53 acres sown in 1944-45, areas increased to 28,812 acres in 1949-50 and an estimated 35,000 acres in 1950-51.

Seed of varieties showing promise was being increased until it was destroyed by rust during the early war years. Walsh, introduced in 1932 from United States of America, proved highly resistant to this disease in New South Wales and Queensland and the expansion of the industry had virtually to await seed increase of this variety. Still newer introductions and locally produced hybrids are expected to outyield Walsh.

Attempts have also been made to reduce damage from Pasmo by making use of seed from crops not affected.

A spectacular control of the destructive *Heliothus* caterpillar which attacks linseed has been obtained by dusting and later by spraying crops both from ground machines and from aeroplanes. Control of this pest is now mainly done by spraying with aircraft.

RICE

In spite of several earlier trials with rice it was not until 1922-23 that successful tests were carried out on the Murrumbidgee Irrigation Area by the New South Wales Water Conservation and Irrigation Commission and the Department of Agriculture, with the three varieties of rice brought back from California by Mr. J.

Brady then Manager of the Leeton Cannery. Within two years 153 acres of irrigated rice were grown on the area. Maximum production of 40,690 acres was reached in 1943-44 when wartime demand resulted in production in the Benerembah and Wakool Irrigation Districts.

The fact that yields of rice in Australia are amongst the highest in the world suggests that production is relatively efficient. The rapidity of development of the industry has necessitated considerable investigational work and also control of production including the limitation of the frequency with which rice can be sown on the same land.

Early trials demonstrated the effectiveness of the Californian methods of controlling barnyard grass by watering.

More recently a study of the rise of the water table has necessitated the discontinuance of rice production on parts of the Murrumbidgee Irrigation Area. A study of the soils of present and potential irrigation areas has been and will be of the greatest importance in preventing a repetition of past errors in establishing irrigation settlements on unsuitable soil types.

Rice breeders have succeeded in eliminating red rice from the original introductions and in isolating high yielding strains of these especially of the leading variety Coloro. They are still attempting to combine yield, quality and greater straw strength.

The value of applying nitrogenous manures to old rice land has been demonstrated but it has more recently been found that a period of subterranean clover pasture has a similar effect on yield, and pastures sown in rotation with rice are increasing. A trial recently commenced to study the effect on soil fertility of various systems of land use in rice production will be watched with interest.

A recent enquiry by Poggendorff (1950) has suggested the probability of growing rice under natural rainfall in the Kimberleys and Northern Territory. Different varieties and methods of cultivation will be required, damage from birds and grasshoppers, if they persist as production increases, will need to be controlled and new diseases may appear to challenge those seeking to establish a new industry in the northern part of the Continent.

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CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN CROPS — 2. TEMPERATE HORTICULTURE

By FRANK M. READ

The last fifty years have seen an intensification of competition in all forms of commercial horticulture with a steady rise in the demand for higher quality. Thus, while the basic skills on which such an intensive form of agriculture is based are very old, horticultural science stimulated by the economic pressure of the last fifty years has been almost wholly built up in this period. Its impact on commercial horticulture has been very wide. Some of the more notable cases only are covered in this brief review.

Plant Nutrition

In the field of plant nutrition, spectacular advances were made following the development of the pot culture technique for determining symptoms of deficiency of each of the major nutritional elements. Because of the difficulty of field manurial trials on trees, especially before the age of biometrics, knowledge of the manurial requirements of fruit trees was scanty prior to 1920. The consistent symptoms disclosed in pot culture work enabled horticulturists to return to field experimentation with renewed confidence and simpler objectives. The phosphatic fertilisers which, among the artificials, had hitherto predominated were shown to be of very limited value to fruit trees and the importance of nitrogen was clearly established.

This work was then progressively extended to the so-called minor or trace elements in which much greater precision was necessary. Iron deficiency had been known for a long time; but zinc, copper, boron, manganese and molybdenum are among others that have been brought under control in the field. The detection of deficiencies by tissue tests has become established quite recently, and it is certain that we are to use straight out chemical analysis and special quick tests of a colorimetric character more and more in our observations on plant nutrition. Plant injection techniques, too, will be further improved as a means of confirmatory diagnosis.

What we need now is a sounder knowledge of the function of the elements in plant nutrition and a clearer knowledge of the conditions which make for satisfactory absorption of nutrients by the large perennial plant with its vast root system so difficult and costly to study. The importance of water in plant nutrition needs no emphasis, but our knowledge of the plant in relation to soil moisture changes has increased enormously in the period under review. There is still, however, ample opportunity for intensified study in this field, particularly perhaps in relation to the irrigation of heavy soils.

Fruit Preservation

While great advances in the technique of fruit canning and of fruit drying have been made during this century and are still being made, the most spectacular scientific advances in Australian work since 1901 have been in the cold storage, gas storage and ripening of fresh fruits.

From 1880 to 1920 advance in this field was of an engineering character. Stores were being built and chosen temperatures could be held with reasonable accuracy under commercial conditions. In 1920, however, most serious losses in all fruits were still quite unexplained. The discovery that low temperature injury was occurring well above the freezing point, in the case of apples up to nearly 40°F. and in the case of citrus up to 50° F., enabled spectacular advances to be made. Prior to this

time, all cool stored fruit was held in the region of 32°F. The increasing knowledge of fruit physiology leading to the handling of fruit as a living organism and the variation in storage temperature at different times of the cool storage life, permitted temperatures of storage to be varied, depending on the length of time the fruit had been in cool store, and this led to important further improvements.

Control of the storage atmosphere, generally known as gas storage, permitted a great extension of safe storage life for some fruits. It was determined that the rate of metabolism of the fruit in store could be varied substantially and its life increased by varying the proportions of oxygen, carbon dioxide and nitrogen contained in the storage air. Commercially, gas storage resolved itself into one or both of the following practices. By storing respiring fruit in a sealed room, the concentration of oxygen is reduced and that of carbon dioxide correspondingly increased. In this simplest form of gas storage, the limit is reached at that level of carbon dioxide, usually between 5 and 10 per cent., at which the fruit is injured. By passing the storage air through a "scrubber", an alkaline solution to absorb the carbon dioxide, the concentration of oxygen can be progressively lowered in the room without raising that of carbon dioxide to undesirable levels. Obviously, low oxygen and high carbon dioxide concentrations slow down the reactions in the fruit.

Some of the most interesting and useful work has been in the study of post-storage fruit ripening. Most fruits we now know will not ripen to good quality except at rather precise ripening temperatures which must be artificially applied in ripening rooms to achieve best results. It was also determined that many fruits, if held too long in cold store, fail to ripen on removal and rapidly deteriorate even though they still appear perfectly sound. In some cases, a pre-ripening treatment of an appropriate temperature for a few days —often in an atmosphere of ethylene— though not altering the appearance of the fruit before storage, will enable post-storage ripening to proceed.

In very recent years, more fundamental studies of fruit physiology have been commenced which may lead to further precision and further advances in commercial practice.

Plant Improvement

Most fruit varieties are of considerable age, and scientific plant breeders have not contributed materially to them in Australia during the last fifty years. Careful work on bud selection has, however, in the citrus industry, brought about a striking gain in the overall quality in citrus fruits. This work has extended recently in citrus propagation to a detailed study of parent trees to establish their freedom from virus diseases. In stone fruits, where the danger of the spread of virus diseases is, on American experience, very grave, extension of such work is most desirable. In fact, all propagation should be based on scientific certification.

During the past fifty years, considerable interest has been taken in the development of better rootstocks for fruit trees, and a great deal of work of this type is going on. Apart from the obvious appeal and importance of this work, it has disclosed some interesting associations of viruses with what had previously been generally termed "incompatibility" in specific stock and scion relationships. It seems more than possible that a great many unsatisfactory unions, now known loosely as incompatible, may be shown to be similarly affected.

Plant Hormones and Growth Substances

With the isolation of plant hormones in the early 1930's and the subsequent production synthetically of many active growth substances, an amazing new field was opened to horticulturists. The first commercial development was the stimulation of roots in propagation by naphthalene-acetic acid and indole-butyric acid and later developments have taken us a long way towards almost complete control of plant behaviour. Control of the abscis-

sion layer next gave us the now almost universally used anti fruit-dropping sprays near to harvest time. Dormancy-breaking materials induced early sprouting of potatoes, while others prolonged dormancy and so extended the storage life of potatoes. The setting of fruits parthenocarpically with the development of seedless fruits on plants which had hitherto required seeds for setting, as in the tomato, soon followed in commercial practice. The initiation of blossom primordia in fruit trees is not yet established; but the commercial control of flowering and fruiting in the pineapple plant has reached the stage when growers can decide the time and amount of fruit at will in suitable varieties.

The problem of delayed foliation, due to the insufficiency of winter cold to bring about fruitfulness in certain temperate zone fruits, such as peaches, has been substantially attacked by growth substances, and growth substances have been successfully used to thin blossom to the desired number and so avoid considerable hand work. This discovery could have a major effect on fruitgrowing methods, for it opens the way to the control of fruit numbers and thus fruit size without recourse, or with limited recourse, to pruning, a practice which is labor consuming and has a number of most unsatisfactory aspects. It is not unreasonable to expect that our control of tree performance in growth and yield will continue to increase with the development of this spectacular line of research, and that a deeper knowledge of tree physiology will also come from it with a piecing together of the many important, but, as yet, somewhat disjointed discoveries of the last twenty years.

Plant Protection

The demand for fruit free of fungous diseases and insect pests on Australian and world markets has increased in the last fifty years to the point where consumers demand clean fruit. It was not always so, and even to-day it is not so in all countries. To meet this demand at lowest cost, steady improvement in plant protection materials and methods of application has occurred during the last fifty years.

On the equipment side, power operated portable spray plants of quite limited capacity were first introduced in the early part of the century. The second and third decades saw stationary spray plants with a central pump and mixing station reticulating spray material under high pressure through pipes for use through hand hoses in all parts of the orchard. During the last twenty years, and particularly during the last ten years, progress has again turned to portable outfits of much greater capacity with the objective of using fixed jets for spraying to reduce hand labor to a minimum. Most recently the use of the aeroplane and helicopter to apply orchard sprays has become firmly established in many countries.

During the last fifty years, insecticides have undergone great improvement, particularly post-war with the use of D.D.T. and parathion. The effectiveness of these insecticides has permitted their application from the air and from the high powered automatic mobile ground machines, for their mode of action does not necessitate a perfect covering of the tree with spray.

The development of fungicides has been slower. In fact, we are only now entering the stage where some of the newer materials are showing promise. There is great need for an advance in this direction.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN CROPS — 3. TROPICAL HORTICULTURE

By W. A. T. SUMMERVILLE

Introduction

Whilst the more important tropical fruits have provided food for thousands of years for many millions of people dwelling in the torrid zone, the plants have received scant attention from agricultural scientists as compared with that devoted to temperate climate species. There have been several reasons for this but the basic one lies in the fact that so many of the better species and the ones which make most appeal to the European palate are soft luscious fruits which cannot be kept in satisfactory condition long enough to permit transportation under normal conditions for any appreciable length of time. This, allied to the fact that the species as a whole demand tropical conditions for growth, and that there has been comparatively little settlement of white men in the region, accounts for the fact that intensive research has been confined to few countries and for but a short period. Work has been done by United States of America horticulturists, British Colonial workers, especially in the West Indies, the Dutch in the East Indies, and by Australians.

The United States workers have added considerably to the store of knowledge, particularly by much fine plant exploratory work, the West Indian workers by more embracing studies, particularly on nutrition and disease control of the banana. Australian workers have taken full advantage of the information gained by such workers and built upon it.

BANANA

In the case of the banana the early Australian work consisted essentially of the testing of the various species and strains available for introduction. A large number of varieties has been imported and extensively tested over a period of almost fifty years. Two criteria of suitability have been used—yield capacity and acceptability to the consumer. This latter has often been almost the determining factor. By far the most successful variety in Australia is the Cavendish. This has a satisfactory flavour, whilst its habit of growth and climatic and soil requirements make its successful cultivation possible over many parts of the tropical and sub-tropical coastal areas of Queensland, New South Wales and Western Australia. A second variety, locally styled Mons Mare, and popularly supposed to be of Queensland origin but possibly a mutant from Cavendish very similar to an Indian variety, is also now of considerable commercial importance. The taller growing varieties such as Sugar and Lady Finger have been largely supplanted by the dwarf types, partly owing to disabilities arising out of growth habit and partly due to the incidence of Panama disease (*Fusarium cubense*).

Apart from varietal testing, research work in Australia has been concerned with problems of disease, nutrition and fruit marketing. Few crops have been as drastically affected by a disease and still survived commercially as has the banana. In the early 1920's the plantations of New South Wales and southern Queensland were devasted by the ravages of bunchy top—a virus disease, the identification, etiology and dissemination of which was the subject of much research, of which the outstanding contribution was that by Magee. On the basis of Magee's findings

a campaign of eradication was evolved which undoubtedly saved the industry in eastern Australia.

On the nutritional questions work has been carried out by F. T. Bowman and H. W. Eastwood, and physiological aspects of nutrition were the subject of a study by W. A. T. Summerville.

As has been stated, transport problems are of major importance with tropical fruits generally, and important contributions to our information on the banana resulted from the research in this field. Many workers have added their quotas, but special mention might be made of that by Young, Bagster, Hicks, Hinton and Holmes in the ripening and transport of bananas in Australia. These workers did much towards placing of the banana on the distant markets in satisfactory condition and thus helped to stabilise the industry. Another contribution of particular note was that by J. H. Simmonds and R. S. Mitchell from which satisfactory control of the squirter disease was the outcome. Based on that work several States now have legislative enactments making the application of control measures compulsory during the colder months of the year when attack by the fungus is most likely to occur.

It can be justly claimed that it is very largely due to the success of research that the banana is still a most important commercial tropical fruit. Paradoxically the industry in Australia is very small within the tropics, and the largest producing State is New South Wales, with the bulk of Australia's production coming 'from between latitudes 27°S. and 30°S.

The banana requires much further research work. Nutrition cannot be said to be fully understood and more intensive physiological studies are now being undertaken in Queensland. By far the greatest amount of work on possible uses of the fruit has been done in the West Indies and it seems probable that more of this type of investigation will be worthwhile in Australia.

PINEAPPLE

The pineapple, now the foremost commercial fruit in Queensland, has had a somewhat meteoric rise in importance, and this is due essentially to the success of scientific workers in combating wilt disease. Though the fruit has been grown in Queensland for very many years, and in limited areas in New South Wales and Western Australia for a shorter period, by the late 1920's commercial production appeared to be doomed. Whilst a somewhat similar disease had been studied in Hawaii, H. K. Lewcock showed essential differences between the troubles in the two countries, and following extensive work devised cultural methods of control which were so successful that the industry in but a few short years revived and has continued to prosper. Now the pineapple occupies a most important place in the horticultural sphere not only in the fresh fruit trade in Queensland but also in the canned fruit export trade.

An industry which depends so largely for its stability on placing fruit either in the fresh state or in specialised canned form on distant markets has naturally demanded that particular attention be paid to transport problems and fruit type, and both of these aspects have accordingly been given considerable attention. Insofar as transport of the fresh fruit is concerned, probably the most important factor militating against success is the so-called water blister disease caused by the fungus *Thelaviopsis paradoxa* (now known as *Ceratostomella paradoxa*). The identification of the cause and methods of control were subjects of work by B. T. Dickson, H. R. Angell and J. H. Simmonds. Whilst the disease is still causing loss this is due very largely to failure on the part of growers to carry out the recommended control methods and at all events is small as compared with the annual loss of £10,000 estimated at the time the work was done.

On the approach to fruit type problems, H. M. Groszmann has made important

contributions, and this worker, in continuing work on physiological problems has studied the effects of plant hormones on induction of flowering.

An important part of the research in Queensland in pineapples has been soil surveys followed by experimental work to determine suitability of soil types for production of this crop.

All available evidence suggests that the pineapple industry will grow in importance, particularly in Queensland, and to some extent also in New South Wales and Western Australia. The plant requires a highly acid soil, however, and considerable additional research is required before management of these soils can proceed on a really sound basis. Further, there are problems arising out of production methods which are now the subject of further investigation. These include better control of fruit maturation time to fit in with cannery requirements, and weed control, which is of particular importance since manual work predominates under the topographical conditions where the crop is largely grown. Mechanisation of cultural methods is being investigated, however, and will probably repay any attention given.

PAPAW

Papaw investigational work has been carried on for a comparatively brief period. The industry grew up in a rather haphazard manner over a period of some thirty years and, apart from spasmodic attention to disease control work, received virtually no scientific assistance until about 1935. At this time it was recognised that if the industry was to take its rightful place as a supplier of a tasty nutritious fruit a systematic attack on its chief problems was required. The first steps were taken by G. W. Agnew and W. A. T. Summerville, who surveyed the existing plantings and made selections of material for use as parents for a breeding programme. The latter worker also inspected plantations overseas and made some introductions. This work has continued, with some interruption during World War II, and has resulted to date in supplying the industry with two fixed varieties displaying superior characteristics.

Plant nutritional aspects have also been studied by Agnew whilst virus diseases, which cause considerable loss, are being investigated by T. McKnight. Probably the most far-reaching work was that by J. H. Simmonds on latent infection in tropical fruits in relation to the part played by species of *Gloeosporium* and *Colletotrichum*. This work is of fundamental importance and any combative measures of a plant pathological nature must be based on the facts elucidated.

There is need for continuance of nutritional studies, plant breeding and disease control. Further, the marketing of these soft fruits will require much further work being done both on transport and storage problems and on methods of usage. Each of these is receiving attention currently and will no doubt continue to do so.

MINOR SPECIES

Other tropical species have received little benefit from scientific research though an increasing amount of attention is now being given to the more promising species, particularly the **avocado.** This fruit promises to assume an important commercial status and the first aspects to receive attention are propagation methods and variety testing. Results to date from the work on propagation have left much to be desired but the requirements of type are now well understood. This fruit will undoubtedly need and receive further attention along these lines.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN CROPS — 4. VEGETABLES

By FRANK M. READ

During the first decade of the century, Australian vegetable growing was still largely in the hands of Chinese market gardeners who applied their age-old knowledge of soil fertility and their painstaking hand methods of production. In the second, third and fourth decades the industry expanded in the hands of Australians to a high level of efficiency with increasing mechanization though still of a rather simple character and limited to irrigation, cultivation and the application of dusts and sprays for insect or fungus control.

As a result of the last war with its enormous demand for vegetables from Australia, the advance in mechanization in all fields of production was spectacular. Co-operation between American and Australian engineers and scientists enabled the modern tractor with its vegetable toolbar and implements to be perfected for multi-row seeding and subsequent care and attention. The industry in the fifty-year period has, therefore, come from a rather primitive condition to an advanced stage of development comparing favourably with any in the world.

Varieties

Systematic introduction and testing of overseas varieties has always been a feature in which seed merchants, growers and research workers have all played a part. Thus, while most of our varieties are of overseas origin, selection within the varieties to obtain greater suitability under Australian conditions has been actively pursued. The discovery of carrot virus by the Victorian Department of Agriculture followed by the selection of carrot varieties for tolerance to this disease, is a special example of very successful scientific work.

Breeding of varieties has not, until recent years, been as extensive as could be desired, but notable work on French beans has been done by Shirlow in New South Wales, by Krone on tomatoes in Victoria, on cucurbits by workers at Hawkesbury Agricultural College, and the potato varieties Moona, Monak and Adina resulting from breeding work of the New South Wales Department of Agriculture are another notable example. Breeding for disease resistance in a range of vegetable crops has been a feature of the recent work of C.S.I.R.O. Division of Plant Industry and the State Departments of Agriculture, often in co-operation.

Seed Certification

In holding the improvements made by selection and breeding of vegetable varities, high quality seed production in Australia is essential. By 1940, Australia was producing a large part of her own seed in the case of brassicas, beans, peas, onions and tomatoes. When overseas supplies were threatened during the war, expansion of vegetable seed growing was organized, and today we probably grow approximately three-quarters of our vegetable seed requirements. The post-war years have seen an important extension of vegetable seed certification schemes in many States. These schemes, though still limited in character, have received unqualified support and, in the future, will grow considerably. Some of the main vegetables covered by work so far are beans, garden peas, onions and tomatoes.

Soil Fertility

Until the horse was largely replaced by the internal combustion engine, ample stable manure was usually available. It was used freely by the vegetable industry to

maintain without much difficulty, and even to improve considerably in most cases, fertility in vegetable lands. During the past decade, the scarcity of animal fertilisers has given rise to deficiencies which have seriously limited production until corrected. Each of the three main fertiliser elements—phosphorus, potassium and nitrogen and several of the trace elements, particularly boron, manganese and molybdenum—have featured in important disorders which it has been possible to correct by appropriate action.

The problem of long range soil fertility in an era when organic fertilisers are going to be scarce, has been tackled in recent years by the laying down of long range rotation systems and alternative manurial and fertiliser practices, including composts, but, as yet, no certain results have come from such experiments.

Selective Weedicides

One of the most costly items of work on the vegetable farm is weeding. The development of selective weedicides has already been of importance in carrot crops where power kerosene of a high aromatic content has, since the war years, been in extensive use. In onion crops, too, sulphuric acid has already been used successfully, but less unpleasant alternatives —potassium cyanate, amine salts of 2,4.D., sodium isopropylxanthate, sodium pentachlorophenate—are now under trial.

Pre-emergence sprays of power kerosene have been effective in preliminary trials with onion crops, and, in the case of pea crops, sodium pentachlorophenate is a possible pre-emergence spray of value. Post-emergence sprays for pea crops are also receiving considerable attention. It can be said that this study of selective weedicides is likely to be one of the most productive lines of research in future.

Plant Protection

Insect pests and fungous diseases have increased in prevalence during the last fifty years, due to their gradual establishment in each district. Plant protection by dusts and sprays and better hygiene is thus an essential part of vegetable growing. Agricultural scientists have greatly aided the vegetable industry in this field by their diagnosis of problems and prescription for correct control. Methods of application have been progressively improved by mechanization. Other important aids to the industry in plant protection have been in the hot water treatment of seed before sowing, and in other cases, notably in peas, by the dusting of seed with effective fungicidal dusts.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN CROPS — 5. WARM CLIMATE CROPS

By W. A. T. SUMMERVILLE

Introduction

Whilst the geographical range over which cotton, tobacco and peanuts are grown is very wide they can, for convenience, be linked with sugar cane as warm climate crops. The climatic requirements of each are such that whilst they can be grown successfully in parts of other States their greatest development has taken place in Queensland, and consequently, with the possible exception of tobacco, have been given the greatest attention in that State.

COTTON

Although cotton has been grown in Queensland since 1860 it was not until the early 1920's that any systematic research work was attempted. In that post-war (World War I) period the scarcity of cotton led authorities to make a determined attempt to foster its production. The measure of success may be gauged by the quick stepping up of acreage from a few hundred to some 14,000, and eventually to 70,000.

However, it was soon evident that cultural, entomological and economic factors in particular would need careful investigation if the industry were to prosper. A most important step was then taken by the opening up of a cotton experiment station at Biloela in the Callide Valley of Queensland in 1924. From that time onwards a comprehensive programme of experimental work has been in operation based primarily on the Biloela station.

Whilst the essential object of the programme of work was to determine basic data on cotton growing, the design was such that the problems arising from this crop were integrated with the general farming potentialities of the hinterland lying roughly 50 to 80 miles from the coast between Rockhampton and Brisbane. Both dry farming and irrigation have been studied.

From the general agricultural standpoint the outstanding portion of the work has been that dealing with the interrelationships between soil nitrate status, soil moisture conservation and soil structure, results of which have been published by Wells in Empire Cotton Growing Corporation Progress Reports from Experiment Stations.

From this has developed an understanding of many problems of general farming of this region, especially where cotton is grown. Thus the value of, and necessity for, rotational cropping, particularly the inclusion of a grassland phase, has been strikingly demonstrated. Other agronomic questions on which much information has been gathered include influence of time and method of ploughing, spacing of plants, nutrient requirements, and irrigation methods. The commercial use of delinted seed for planting purposes was one contribution of special value made by Queensland investigators (L. Hodge, 1933).

Initially, the only varieties available were those from other countries, and a comprehensive programme of testing of a wide range of types was required before promising varieties could be obtained from which to develop strains suitable to Queensland conditions. Much progress was made by intensive strain selection and testing which provided varieties eminently suited agronomically to local conditions. The necessity to supply jassid resistant cottons led, however, to the

development of strains incorporating the requisite type and degree of hairiness into a high yielding, good staple length commercial variety, which may be cited as the greatest contribution by the plant breeders (Marriott, 1943).

Entomological problems have been given a great deal of attention, cutworms, jassids, bollworm and stainers being the major pests on which work has been done.

The economics of cotton growing have continually presented problems. In the early days of the industry revival, the growers worked on the basis of a guaranteed price, and in 1926 the Queensland Cotton Marketing Board was established. This body has since been charged with the responsibilities of marketing the crop and to discharge this function has operated ginneries at Rockhampton and Brisbane. During the post World War II period production has fallen off very considerably, due largely to the higher returns for other primary products which can be produced on lands suitable for cotton. In 1950, world shortages, a higher guaranteed price and a grant towards debt reduction on ginneries, stimulated production, and there is now an upward trend in acreage.

Until the industry once more reaches stability and attains appreciable economic status it is probable that the major investigational work will be on breeding aspects with serious attention also to the development of mechanical harvesting. This latter will necessitate not only an approach on the mechanical side but also on the plant, since bush type, defoliation and correlated factors will be involved.

TOBACCO

Tobacco is amongst the most intricate of agricultural crops to produce and market. This is so chiefly because of three factors. Firstly, the intensive nature of the work, resembling as it does market gardening on a large scale and requiring a preliminary seed bed operation; secondly, the agronomic difficulties associated with the production of acceptable leaf; and, thirdly, the final value largely depending on the success of curing by a rather exacting technique carried out by the grower.

Problems may be said to start with the seed bed, and apart from the normal approach to determining the best methods of preparation, two pieces of research, one with an entomological basis and the other plant pathological, have been of particular merit and value. The entomological question involved combating seed harvesting ants which in North Queensland cause havoc by removing the seeds immediately after sowing. Smith and Atherton evolved a highly successful simple technique using the mechanical effects of a sand topdressing (J. H. Smith, 1944). The pathological one concerned the control of blue mould in the seed bed by the vapour treatment method and was so successful as to change the status of this previously most feared disease. Angell and his co-workers must receive much credit for this contribution.

Both yield and quality are closely correlated with soil conditions and general environment. Consequently, in all States where the crop has shown possibilities of success, trial plantings have been made over a wide range of soils and climatic conditions. The basic requirements of the plant and the overall possibilities of many districts of the three eastern States and Western Australia are now fairly well known and the agronomic problems at least well defined. Nutrition, water usage, and suitable rotations have all been given attention. Cartmill, Cass-Smith and McDonald have been prominent amongst the authors on these subjects in accounts of important experimental work which have appeared over the years in journals of the State Agricultural Departments of each of the producing States. Special contributions to the knowledge of diseases and their control have been made by A. V. Hill, on Frogeye Disease of Tobacco; L. F. Mandelson and E. C. Tommerup on Yellow Patch of

Tobacco Seedlings; and L. F. Mandelson on general tobacco diseases.

Smokers are very discriminating in their choice of tobacco, and as smoking quality is intimately associated with variety of plant, environment and curing, an integration of many lines of research is demanded. Insofar as variety is concerned the bulk of the work to date has been essentially the testing of imported varieties, particularly from U.S.A. More recently breeding work has been undertaken by C.S.I.R.O. officers and this programme has taken cognisance of both leaf quality and disease resistance, with special reference to mosaic disease. At present the most favoured varieties are Gold Dollar, Yellow Special, Mammoth Gold, 400-401 and Kelly, all of which originated in the U.S.A.

Probably the most significant single development in the industry in Australia was the changeover from sun and air curing to flue curing which took place around 1927 as the direct consequence of consumer preference. This change had effects not only on the method of handling the crop but on determining varieties and suitability of soil types. This had far-reaching effects in the industry, resulting in changes in favoured varieties and, after much investigation, in the opening up of new districts for production and the abandonment of others.

Harvesting methods, grading, and curing have each received attention by such workers as Hamilton, of Queensland, Sharp, of Western Australia, Marks, of C.S.I.R.O., Tregenna, of New South Wales and McDonald and Coghlan, of Victoria.

For many years growers were very dissatisfied with returns. This dissatisfaction rose largely out of the great difficulty in appraisal of leaf quality. Appraisal is so largely based on qualitative rather than quantitative data that some degree of dissatisfaction is almost inevitable. A great deal of effort by growers, manufacturers and field and marketing officers has been directed to smoothing out the difficulties, and whilst it cannot be said that the problem is as yet completely solved much progress has been made and sufficient harmony achieved to allow the industry to develop along stable lines.

Tobacco growing shows every indication of big expansion and it would appear that further investigational work will be required in every phase of tobacco growing and marketing. On the plant breeding side the search for superior varieties by both selection and breeding is necessary and is proceeding. Agronomic questions also require further probing with perhaps special emphasis on crop rotation, since much of the evidence suggests that monoculture of tobacco will not succeed for any appreciable number of years, particularly when nematodes are present. Sources of heat are likely to require attention because wood, now the chief fuel used in the curing, is gradually becoming more costly and difficult to obtain. Curing is, too, often somewhat haphazard, and better techniques might result from further investigation. It seems inevitable that further investigation will be called for into the intricate and important subject of leaf quality.

SUGAR

In few agricultural industries anywhere, and certainly in no tropical one, has the value of research been given more practical recognition than in the case of sugar, and Australia has been in the forefront in this regard. The Sugar Experiment Stations Act of 1900 set up machinery for the establishment of research stations and as the machinery was promptly put in motion the sugar industry became the first agricultural industry in Australia to possess its own research organization.

The Bureau of Sugar Experiment Stations, which, for administrative purposes, is placed within the Queensland Department of Agriculture and Stock, is subject to a measure of industry control, being very largely financed by the producers, and has its origin in the above

Act. This Bureau is staffed by a team of scientists covering virtually every phase of sugar production and conducts research into both field and mill problems. The facilities include four Experiment Stations appropriately spaced through the sugar belt, and in these plant breeding, pest and disease control, and agronomic and soils investigations are pursued. A mill technology section, staffed by engineers and applied science graduates, works largely in conjunction with the mills.

The Bureau issues a series of technical communications in which are to be found accounts of the research work undertaken, and reference should be made to these for detailed information, or to a Bureau booklet, "Fifty Years of Scientific Progress" for an extensive review.

The control, and in the case of downy mildew and gumming disease the eradication, of cane disease represents an outstanding example of the value of sound legislative action based on proven biological data and is one of the most notable achievements of the Bureau's pathologists. Thus, though Fiji disease, leaf scald, chlorotic streak, and dwarf disease command attention, the loss today from these is insignificant.

The plant breeding programme has, of course, been shaped with due consideration to disease resistance as well as yield, and the degree of success of this work may be gauged by the fact that of the six and a half million tons of cane produced annually in the State, some 60 per cent. is of Queensland bred varieties.

Soils work has been intensively developed and appropriate fertiliser mixtures determined for each of the soil types of moment.

In the field of entomology, many years of patient work has been made very fruitful by the availability of benzene hexachloride, which enables excellent measures of control of the two most important classes of pests—cane grubs and wireworms.

The sugar industry is fortunate in that it is one of the few agricultural ones which markets its product in a standardised manufactured form. However, this has created certain problems, particularly in extraction techniques and schemes of payment, but techniques have been developed which on the one hand ensure a very high recovery percentage, and on the other just returns to the grower.

Further work will no doubt continue on much the same lines as over the past 50 years, with perhaps particular emphasis on plant breeding problems. The extending use of hormone type weedicides is now receiving attention, and having regard to the soil and climatic conditions in which the crop is grown it appears inevitable that increasing emphasis will be placed on this work.

PEANUTS

Although peanuts have been grown in Australia for many years, before about 1923 the acreage was so small that the production could scarcely be termed an industry. A measure of tariff protection given to the industry brought a quick response, and in the following five years the acreage in Queensland rose from 210 to almost 10,000 and by 1938 was in excess of 20,000. Since the war it has remained fairly stable in the vicinity of 25,000 to 30,000.

Only two varieties are grown commercially — Virginia Bunch and Red Spanish. Within these two varieties a long term programme of strain selection has been pursued, and virtually all peanuts produced in Queensland for many years have been selections or recent products of selections by plant breeders of the State Department of Agriculture and Stock.

Apart from this work of selection investigation has been conducted into agronomic problems and nutritional requirements of the plant. In the former field the greatest difficulties have arisen out of the monoculture so frequently practised by peanut growers. On the undulating country of the South Burnett district, where the bulk of the crop is pro-

duced, this unbroken sequence of the one row cultivated crop has led to serious depletion of plant nutrients following loss of soil structure and loss of soil by erosion.

Thus the evolution of a suitable rotation programme has called for action. Results have shown that the inclusion of grass in any peanut rotation is essential. The translation of findings into farming practice remains a continuing task for the agricultural scientists in the area.

Fortunately the peanut is not normally subject to severe attack by insect pests, but crown rot, a disease caused by fungi, constitutes a very serious menace. In seasons when continuous rain has fallen during the drying of the harvested plants, this disease has seriously depleted supplies of reliable seed for the following planting. Morwood (1945) has demonstrated the value of seed treatment for the partial control of the organism involved. The disease is probably the most serious limiting factor in the expansion of the industry.

Production is mechanised from planting to threshing, with the exception of some phases of harvesting where manual labour is still required. Plants are cut by machine, and pulled and stooked by hand, but recent developments suggest that cutting, pulling and windrowing can be done mechanically. Normally stooks are taken to a stationary thresher, but experimental pick-up threshing machines now offer bright hopes of success.

The marketing of peanuts has called for some investigation chiefly centred around conditions of storage, with particular reference to moisture content. The Queensland Peanut Marketing Board, established in 1924, handles virtually the whole crop and an associated co-operative organization operates extensive plant for storage, shelling and cleaning on behalf of the growers.

The future will call for further lands on which to grow the crop and as these are found the usual problems of nutrition and farming practice will demand the attention of soil technologists and agronomists.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN LIVESTOCK INDUSTRIES

By GRAHAME EDGAR

During the early years of this century stock owners in Australia were beginning to realise, the economic significance of animal disease as it affected the prosperity of their industries. During the nineteenth century they had experienced the ravages of Anthrax through their flocks and herds and were appreciative of the benefits conveyed by vaccination. Scientists had achieved something in effecting a substantial saving by protective vaccination against this disease.

Successful Eradication of Some Exotic Diseases

Pleuro Pneumonia and Cattle Tick had gained entry into the country and when the paucity of Veterinary services fifty years ago is considered, it is remarkable that other exotic conditions, notably Foot and Mouth Disease and Rinderpest, did not become established in the herds and flocks of Australia. Both diseases have been introduced at different times, notably Rinderpest into Western Australia in 1923, but early recognition and the adoption of radical measures have in every instance successfully effected their eradication.

Swine Fever has gained a foothold twice within the last thirty years and has been eradicated only at considerable cost and effort. Victoria and New South Wales were affected in 1927-28 and Western Australia and New South Wales in 1942-43. In the latter outbreak the disease was not eradicated until Western Australia had lost half its pig population.

The Establishment of Faculties of Veterinary Science

The establishment of the Faculties of Veterinary Science in the Universities of Melbourne and Sydney during the early years of the century was the initial step of major significance in planning the attack on problems of the Australian Livestock Industries. The graduates from these schools (unfortunately Melbourne ceased to function as a teaching Institution in 1928) and later Brisbane which was established in 1935, have provided the training for those who have undertaken these studies.

Diseases of Indigenous Fauna

Australia has been fortunate in that the indigenous fauna have not been ruminants capable of acting as reservoirs and transmittors of serious infectious diseases. The marsupial fauna are relatively insusceptible to many of the serious animal plagues which have proved a constant drain on the livestock industries of other countries, notably South Africa and South America.

Diseases and Parasites in the Sheep Industry

On the other hand the very remarkable development of the sheep and wool industry of this country has created a number of problems of considerable economic significance to that industry, and whilst these problems existed, and had been recognised in other sheep raising countries, it has been through the efforts of Australian research workers that many problems have been solved and the answers made available to the world. The losses from Black Disease or Infectious Necrotic Hepatitis in sheep amounted each year to several million pounds and occurred on some of the best grazing country of New South Wales and Victoria, much of which in consequence came into disrepute. Some areas on this account were given over to cattle raising.

Black Disease and Liver Fluke

During World War I, much investigational work on the Black Disease problem was undertaken by Dr. Sydney Dodd of the Faculty of Veterinary Science, University of Sydney. He showed that the focal point of this disease was located in the liver where certain necrotic changes were due to infection with an anaerobic organism, subsequently identified as *Clostridium oedematiens*. Dr. H. E. Albiston of Melbourne substantiated Dodd's findings and advanced certain hypotheses in the etiology of the disease.

Edgar working from the Glenfield Research Station in New South Wales showed that the organism *Cl. oedematiens* was carried in the livers of healthy sheep in Black Disease districts. Dr. A. W. Turner confirmed this finding and established the link between the onset of the disease and the invasion of the liver by immature fluke. Turner also succeeded in producing a vaccine which has proved very efficacious in controlling losses from Black Disease.

Concurrently with the solution of the Black Disease problem, McKay established that the intermediate host in Australia of the Liver Fluke, *Fasciola hepatica*, was the small water snail, *Simlimnea brazieri*.

Clunies Ross and Seddon at this time showed the value of carbon tetrachloride as an anthelmintic against Liver Fluke and demonstrated that it could be readily and safely administered to sheep as a drench in liquid paraffin by means of a syringe.

The value of anti-snail measures in reducing the incidence of Fluke was also demonstrated at this time by Clunies Ross who studied the binomics of *Simlimnea* and showed that copper sulphate in dilutions as high as 1 in 1,000,000 was highly effective in destroying this water snail.

There is no doubt that this bracket of knowledge reorientated the whole of the sheep and wool industry on the tablelands and slopes of Eastern Australia.

Entero-toxaemia

The solution of the Black Disease and Liver Fluke problems was closely followed by the work of Dr. H. W. Bennetts in Western Australia on Entero-toxaemia of sheep and lambs. This rather unusual disease had occurred each year with regular incidence in the Beverley District of Western Australia, especially in ewes and lambs grazing on succulent pastures. Bennett's work disclosed that death was due to the development in the gut of an exotoxin of the anaerobic organism, *Clostridium welchii Type D*. A satisfactory means of control was established by immunisation with a vaccine. This work gave a lead to research workers in other Australian States and the disease was identified in South Australia, Tasmania, Victoria and New South Wales and the occurrence of Entero-toxaemia in other sheep raising countries of the world has now been confirmed.

Foot Rot

The etiology of Foot Rot was revealed by Beveridge and a method of control determined which in its application over the years has been shown to be particularly sound.

Mycotic Dermatitis

Mycotic Dermatitis of sheep was identified by Bull as being caused by a fungus, *Actinomyces dermatonomus*. The disease is most prevalent following prolonged moist conditions. Edgar and Keast found that this disease was not restricted to sheep but it could infect horses and cattle.

Scabby Mouth

Infectious Labial Dermatitis, popularly known as "Scabby Mouth" has caused considerable economic loss amongst fat lamb breeders. This disease has been identified as being caused by a virus of the *Variola* group. Man shows some degree of susceptibility and the appearance of the disease amongst a flock at shearing has, in recent years, created much industrial unrest. Hayston at Glenfield produced a vaccine which affords a high degree of protection and has proved of inestimable benefit in districts where the disease is enzootic.

The Sheep Blowfly Problem

During the late 1920's and early 1930's considerable knowledge accumulated on the sheep Blowfly problem as a result of the research work of a number of investigators—Seddon, Belschner and Mulhearn, presented the initial clear picture as to reasons why sheep are struck by Blowflies. They showed that it was possible to classify sheep as to their relative susceptibility to Blowfly strike in the crutch. The essential factor in rendering sheep susceptible was the existence of skin folds or wrinkles in the perineal region. The animal devoid of wrinkles or possessing a plain breech was rarely struck whilst the susceptibility to strike increased in direct proportion to the degree of wrinkliness or fold development. The identity of the flies involved in primary and secondary 'strikes" was studied by Tillyard and his co-workers. Later Mules in South Australia evolved a technique for the removal of the breech folds. This procedure, which has become known as the Mules Operation, has been investigated by a number of research workers. It was modified by Gill and Graham and the value of the operation to-day is widely recognised and has been adopted as a standard practice in sheep husbandry in many parts of Australia.

Intestinal Parasites

In the field of parasitology the progress of knowledge over the last fifty years has been remarkable. Clunies Ross and later Gordon in their studies of the epidemiology of intestinal parasitism of livestock, have advanced the knowledge of this important problem. New and more efficient anthelmintics are available to-day.

Nutritional Diseases

In the field of animal nutrition the advance in knowledge has been amazing. Fifty years ago nothing was known of deficiency diseases which were vaguely attributed as "something" associated with climate. In certain areas stock were known to chew bones at times and it was presumed that the animal's ration was deficient in calcium and phosphorus. It has been, however, in the trace element deficiencies that some of the most spectacular work has been achieved. Filmer and Underwood showed that the so-called Enzootic Marasmus of Western Australia was a cobalt deficiency. Renmark Disease of Cattle was also a cobalt deficiency which could be both prevented and cured by the administration of infinitesminal amounts of cobalt salts.

Marston and his co-workers have shown that Coast Disease of South Australia is the result of deficiency in availability of copper and cobalt. This finding has had the effect of again bringing into production much valuable grazing country in the south-east of South Australia.

Similarly Bennetts has demonstrated that Enzootic Ataxia of sheep or Gin Gin sponsive to minute amounts of copper.

These findings, whilst of considerable significance to the Australian Livestock Industries, have supplied the answer to similar problems in other parts of the world.

One of the serious problems of the fat lamb industry in the more closely settled areas has been the "Toxaemic Jaundice" complex. Investigations have revealed that this condition comprises two entities (1) an abnormal condition of the liver resulting from eating the plant *Heliotropium europaeum*, and (2) a chronic copper poisoning.

A considerable amount of information has been accumulated on plants which are poisonous to livestock.

Poultry Diseases

The development of the poultry industry in Australia has led to a comprehensive range of investigational work into the diseases of birds. It is a matter for congratulation that Australia is the only continent in the world which is free of the industry's greatest scourge—Newcastle Disease. Much is known of the incidence and methods of control of the infectious diseases of poultry in Australia, and the recent development of a vaccine against the Spirochaete disease, Fowl

Tick Fever, offers a solution to this problem of poultry raising in inland districts.

Our Major Cattle Diseases

In 1920 Contagious Pleuro Pneumonia was endemic in the Southern States of Australia. To-day these States are free of the disease and occasional outbreaks are seen only in introduced cattle from Queensland and the Northern Territory.

Another achievement of note is the retention of the Cattle Tick in the extreme north-eastern corner of New South Wales and the eradication of the parasite in some districts now on the perimeter of the Quarantine Area.

Over the years Mastitis and Brucellosis have proved probably the cause of the greatest economic loss to the dairying industry in Australia. Strain 19 vaccine, which is a viable product, was evolved in the United States and the widespread adoption of its use on heifers in this country during the last decade has had the effect of reducing abortion in heifers from approximately 23 to 3 per cent.

In the field of Bovine Mastitis research, Australian workers have made notable contributions. Murnane, in his extensive studies of this problem, has shown the value of udder infusion with penicillin in the treatment of *Str. agalactiae* form of Mastitis. There is rapid response to the treatment and return to normal production.

Animal Breeding

In the field of animal breeding, the Merino sheep has shown the most striking evolution. A comparison of the grand champion rams of to-day with those of thirty years ago reveal outstanding differences. Breeders have concentrated on a reduction of fold development with very good results. Many workers during the last decade have commenced an examination of the dominant and recessive characters of the Merino by progeny testing. This work has also revealed the presence of Merit Sires in studs.

Kelley has examined the value of the Zebu in the development of a tick resistant type of crossbred beef animal for tropical Australia.

The foregoing is a very brief catalogue of some of the results of research into problems of Australia's Livestock Industries, which have contributed significantly towards their economy.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN INSECT PEST CONTROL

By H. G. ANDREWARTHA

The basic problem in insect pest control in 1951 as in 1901 may be stated quite simply. In order to be a pest a species must have two qualities. It must be associated with crops, livestock or other products of value to us and it must be capable of maintaining high numbers. Our job is to learn how to modify the environment of the pest species in such a way that its numbers will be reduced to, and if possible maintained at, a low level which will not do appreciable damage. In general we have the choice of three broad fronts on which to attack the problem. We may *starve* the enemy out. That is we may reduce the amount of food available to the pest species by a judicious use of crop rotation or resistant varieties. But it should be noted that this may be extremely difficult, for "agricultural progress" usually consists of spreading great feasts of good food for the insect pests where before there was none. (Without our agronomist colleagues we entomologists might soon be out of a job!) The second alternative is to *poison* the pests. This is done by introducing into the environment some suitable chemical which will neither leave a residue poisonous to ourselves nor yet destroy an appreciable number of the beneficial species in the area. The year 1951 is characterised by a tremendous hum of activity in this field. For our chemical colleagues have just recently presented us with a number of entirely revolutionary poisons and we are busy learning how not to poison the wrong species with them. Finally we may introduce a new *predator* (usually another insect species) to *eat* the pest species. This is the best method of all when it works but unfortunately the situations for which it is appropriate are strictly limited in number. However, this is also the most popular method with farmers and we can reasonably expect them to continue to insist that at least a few entomologists be retained to continue the search for new parasites.

In 1901 most of the Australian States employed an entomologist either in the Department of Agriculture or in the Museum. All these men had graduated from the ranks of the amateur naturalists. In New South Wales W. W. Froggart, who had been appointed Government Entomologist in 1896 at the age of 38, was a staunch advocate of chemical methods for controlling insect pests. He knew that many species were preyed upon by natural enemies but he had little patience with those who thought that we could materially alter the balance of nature in our favour by playing about with the agencies of biological control. The poisons which were available at this time were few and simple. The arsenicals Paris Green and London Purple were popular, extracts or diffusions of Pyrethrum and Tobacco were available, and for sap-sucking insects that did not yield to these there was always home-made kerosene emulsion. The American George Compere, who was appointed Government Entomologist in Western Australia in 1901, had little time for this school of "kerosene pump" entomologists. He believed that it was only necessary to seek long and diligently enough in order to find effective parasites for most, if not all, the pest species. He certainly worked hard and we owe a number of valuable introductions to him. In Victoria Charles French Senior was busy on his "Handbook of Economic Insects of Victoria," which was

published in five parts, appearing between 1891 and 1911. It contained numerous coloured plates and a wealth of biological information which makes it still worthy of consultation on occasion.

In 1951 in Australia, as elsewhere in the world, entomological knowledge is being advanced by many university-trained professional scientists and only a few amateur naturalists. But however much we may change our methods, however much we may add to the storehouse of knowledge and technical "know-how", the basic problem remains much the same. And the history of progress during the last 50 years is largely the story of a pendulum swinging between the extremes of theories that were already current in 1901. Despite a number of most useful successes, Compere's enthusiasm for biological control was not sufficiently born out by practical results. During the early years of the century interest swung towards chemical control measures. This led to, and was enhanced by, a number of technological improvements in the old-established poisons and the introduction of some new ones. The pendulum swung strongly back towards biological control with the appointment in 1928 of R. J. Tillyard as the first Chief of the C.S.I.R. Division of Economic Entomology. Just as Compere had been inspired by the success of the Australian ladybird, *Novius cardinalis,* introduced into California to control the scale insect *Icerya purchasi,* so Tillyard was inspired by the equally striking success of the American wasp *Aphelinus mali,* introduced into New Zealand to control the woolly aphis of apple. The pendulum swung again with the discovery of D.D.T. and its spectacular use during war to inhibit the spread of mosquito-borne malaria and louse-borne typhus.

Will the pendulum continue to swing? Yes, I believe it will under the impact of new discoveries and powerful personalities. But I think the oscillations will be damped. There will be less occasion for extreme fashions as our knowledge of the basic principles of population ecology is increased. Australia is fortunate in having active workers in this field. In Canberra Dr. A. J. Nicholson is making a thorough study of competition in relation to the ecology of populations, using both laboratory experiments and mathematical models. At the Waite Institute the school of insect ecology founded by the late Professor James Davidson has studied the ecology of natural populations and has been particularly interested in the influence of weather and climate on the distribution and abundance of insects. These are complementary studies. As they grow closer, as they will with progress, we shall come much nearer to a full understanding of the basic problem of economic entomology. The more we understand how the pest species is able to maintain high numbers the more this knowledge will illuminate our efforts to control the pests. We may even reach that dizzy pinnacle of understanding from which it will be possible more often to use the *starvation* method against species which are, today, well-established pests requiring the annual expenditure of great quantities of poisons and labour in our efforts to control them.

CONTRIBUTIONS OF AGRICULTURAL RESEARCH IN FUNGICIDES AND WEEDICIDES

By C. J. MAGEE

FUNGICIDES

Although Julius Kuhn recommended the use of copper sulphate as a seed treatment for the control of bunt in wheat as early as 1873, one of the most important researches in fungicides at the turn of the century was still the development of an efficient seed treatment for this disease. Jensen, in 1888, in Denmark, had contributed the hot water treatment for cereals (later modified by Kellerman of U.S.A.) and Bolley in 1893 had introduced formalin and corrosive sublimate as new seed disinfectants. It is doubtful, however, judging by William James Farrer's thoughful discussions on his detailed experiments on bunt in wheat (*Agric. Gaz. N.S.W.* XI: 335-344, 1900; XII: 419-430, 1901; XIV: 206-216, 1903; XVI: 1248-1255, 1905) whether even a fairly satisfactory seed treatment for this disease was in wide usage in any part of the world. It is known that Farrer maintained regular correspondence with wheat investigators in Europe and North America and in view of this it is considered safe to rate his wheat seed treatment investigations as the leading pioneer work in this field. Daniel McAlpine was doing similar but less detailed work in Victoria and there was contemporary work in Europe and U.S.A.

Farrer's experiments were aimed at determining the relative merits for bunt control of bluestone, formalin, corrosive sublimate and hot water, great care being taken to assess their effects on different varieties, the protection afforded against re-infection and their safety, both to the grain and the operator. After several years' examination he concluded that the bluestone and formalin dips were to be preferred, the former having the advantage of preventing re-infection of the seed, but he was not satisfied and longed for a bunt resistant variety. In 1905, referring to the seed injury problem, Farrer states:—"None of the treatments which are in use are, as a matter of fact, entirely satisfactory. If we can only get varieties whose resistance to the infection of bunt is sufficient to cause treatment, or at any rate, severe treatment with fungicide to be unnecessary, the saving of seed will be great enough to be of very substantial importance".

Early in the century, too, McAlpine was investigating the use of Bordeaux mixture and modifications of it for the control of black spot of apple. Good results were obtained from the outset with copper compounds, but even as late as 1907 (*J. Agric. Vic.* 5: 365, 1907) a trial was conducted in which "Cooper's Fluid Sheep Dip" was compared with Bordeaux mixture and "Copper soda" for the control of this disease. Prior to the black spot work, Bordeaux mixture had been found useful for control of peach leaf curl and other stone fruit diseases. As early as 1891 the value of "copper treatment" for leaf curl had been demonstrated in South Australia (South Australian Register of 30th March, 1892). McAlpine in "Guide to Growers No. 27" issued by the Department of Agriculture, Victoria, in 1896, described peach leaf curl and recommended spraying with Bordeaux mixture. "Among other substances used, a spraying with lime, sulphur and salt in Winter, originally used as sheep dip in Australia and known as 'Victoria Lime and Sulphur Dip,' was found to be an effectual remedy for this disease". (McAlpine; "Fungus Diseases of Stone Fruit Trees in Australia and

their treatment". Dept. of Agric. Victoria. 1902).

It is of interest that from "Victoria Lime and Sulphur Dip" sprang modern lime sulphur. In searching for a control for San José scale, A. T. Covel in California in 1881 tried Australian Sheep Dip with success. Later the salt was omitted from the mixture and lime sulphur came into use about 1900 as a scalicide, and soon began to be recommended also in the eastern States of U.S.A. for the control of fungous diseases, particularly of stone fruits to which copper foliage sprays were proving toxic.

Increased attention was directed to the use of fungicides and especially to the techniques of their application when Irish Blight of potatoes appeared in all Australian States in 1909 and reached epidemic proportions in the eastern States in the wet Spring of 1910 and the wet Autumn of 1911. There had been previous experiments in Europe and North America to serve as a guide in dealing with this disease and many plots to demonstrate the merits of sprays were established throughout Australia. It appears that preference was generally given in recommendations to "copper soda" over the "well-known Bordeaux mixture" because it adhered longer to the foliage, "was more easily prepared" and "was not likely to clog the nozzles of the machines".

Australia's most valuable contribution so far to fungicide technology was George Percy Darnell Smith's demonstration of the value of copper carbonate dust as a cereal seed treatment (*Agric. Gaz. N.S.W.* XXVIII: 185-189, 1917). Darnell Smith's method was unique in that it was the first time a dust was proposed for seed treatment (Bayer dust, Uspulun-Trockenbeize did not appear on the market until 1925), but its great value and rapid adoption came from the realisation by wheat growers that it was easy to do compared with bluestone or formalin dips, the seed could be treated at any time before sowing, there was no need to take great care in disinfecting the seed containers, the seed was not wetted, causing swelling and sometimes heating and drilling trouble, and most important, it did not injure all these advantages the use of copper the seed but instead had a protective action and increased the stand. Because of become standard practice with wheat carbonate dust and later copper oxychloride and organic mercurial dusts has growers in Australia and throughout the World, and bunt, one of the oldest of known plant diseases and formerly one of the most destructive to wheat, has diminished greatly in importance. The annual cost of maintaining bunt in control by seed treatment, however, must not be overlooked. While this constitutes a challenge to plant breeders, as seed injury following treatment formerly was to Farrer, there is a hope that wider use of more efficient fungicides (e.g., hexachlorobenzene, "Panogen," etc.) will eventually eradicate bunt.

Another notable contribution was made in 1934 by H. R. Angell in drawing attention to the fungistatic properties of the vapours of certain hydrocarbons in controlling downy mildew of tobacco in covered seed beds (*J. C.S.I.R. Aust.* VIII, 1935). This appears to have been the first occasion on which vapours were employed in plant disease control (Darnell Smith had tried formalin vapour without success as a seed treatment for bunt in 1916). Angell's method, with modifications, came into world-wide use.

Fungicides were first mainly used in Australia for cereal seed treatment and for the control of diseases of deciduous fruits. From 1918 when downy mildew of grapes made its appearance, vines also have required regular application of sprays and it has also become the practice to spray citrus trees. During the past 30 years increasing culture of vegetables has brought in many fungicide routines. For each crop much detailed work has been necessary in devising the most efficient fungicide programme. So many variable factors have been involved that an empirical approach has been the

only one possible. Records of most of this work have been published and the results together constitute a very valuable contribution to knowledge. Among the fungicides in use, compounds of copper and sulphur still hold pride of place, not so much because they are the most efficient, but because they are also the cheapest available. The trend is, however, towards their displacement by "organics" and already specialised uses have been found for salicylanilide, chloronil and a few others. There is reason to suppose that this trend will ultimately lead to "specifics" for most pathogens or groups of pathogens.

WEEDICIDES

Research into weedicides in Australia appears to date back to attempts to control prickly pear by chemical means. Some success in dealing with this pest was achieved with arsenical sprays and injections, but the procedure proved too costly for general use. Arsenical preparations were regularly employed at least as early as 1925 in weed killing by spraying in banana plantations in Southern Queensland and Northern New South Wales. Various commercial formulations containing arsenic appeared on the Australian market and were the only weedicides used in agriculture until sodium chlorate attracted brief attention. It was found that there were few avenues where sodium chlorate had an application because of the dangers of ignition associated with its use.

During World War II, the use of weedicides (kerosene and dinitro mixtures) was introduced into row crop farming in Australia under guidance from farm advisers sponsored by the United States Army. Later, with the release of wartime information on 2,4,D. and related hormones, a new era dawned in weed killing. For the first time it was agreed that the chemicals and labour involved were a match for the weeds. Interest has quickened and weeds are no longer spoken of collectively, but each important species is up for individual examination with a view to control.

Early success followed the use of 2,4,D. on water hyacinth in coastal rivers and for the control of weeds in home lawns and sports turf. Considerable progress has been made in controlling weeds in pastures, notably Bathurst, Noogoora and galvanised burrs by using plant hormones, but their use for weed control in cereal and other field crops has been slow in developing in Australia. It has been determined, however, that many of the more important weed competitors in these crops can be dealt with by hormone spraying.

It is of special interest that close liaison has been established between the chemical industry and agricultural research workers in the production of suitable hormones and formulations for dealing with individual weeds. As a result, recently 2,4,5,T. in a number of formulations has proved highly successful in eradicating blackberry from pasture land and the trend is that one by one most, if not all, of our important weed pests will eventually be matched with a chemical formulation.

EDUCATION IN AGRICULTURAL SCIENCE IN AUSTRALIAN UNIVERSITIES

By S. M. WADHAM

Background

The currents of University development normally flow in the well-defined channels of the traditional schools of classics, language, mathematics and science. Now and then a new course is devised somewhat divergent from the old because new fields of knowledge have opened and some enthusiastic individual provides a sufficient stimulus to divert part of the momentum of the governing body. Any large innovation usually starts as a result of action outside the University, just as a tree may divert part of the course of a stream.

In Britain, the stimulus for the greater application of Science to Agriculture developed as a result of the long decline in rural prosperity which started in the 1870's. Various educational attempts were made to mitigate the rural depression, mostly in the direction of supporting agricultural colleges. However, a few people with confidence in the potentialities of science to assist farming were able, either directly or through governments, to stimulate universities to start agricultural courses and to add to the research programmes which had been going on for some years at Rothamsted and a few other places. Similarly in the United States the Land Grant colleges brought the idea of agricultural education into prominence.

Genesis of the Australian Faculties of Agriculture

Following these leads, pressure began to develop in Australia for attention to the application of science to agriculture. Heads of departments in the various states, such as H. C. L. Anderson in New South Wales and Dr. S. S. Cameron in Victoria, recognised the need for training men for such work. Australian universities were not in an advanced stage of development at the opening of the century, and had no funds to devote to such new studies; while parliaments, imbued with the characteristic worship of "the practical man," were not prepared to move of their own accord. External stimulation by enthusiasts was therefore needed to start the university agricultural schools.

In Adelaide, Roseworthy Agricultural College became formally associated with the University in 1905 when students with the College Diploma, who had matriculated, were given status in the Faculty of Science, and permitted to take a B.Sc. degree after passing a special two-year course, while science students could spend two years at the College in partial fulfilment of the requirements for the degree. The course did not make much progress until the foundation of the Waite Institute in 1924 led to a great upsurge of interest in the subject.

Melbourne went a stage further in 1905 and created a Faculty; however, this had no special staff until 1911 when the State Government provided £1,000 a year for five years for the salary of the first Professor, the late Dr. T. Cherry, whose appointment lapsed in 1916 while he was on Active Service overseas.

In Sydney the initial funds for the Schools of Agriculture and Veterinary Science came from the Berry Estate, which provided £5,000 to the University for these purposes; the University's acceptance of this sum was provisional on the Government agreeing to provide buildings and equipment. Professor R. D. Watt arrived in 1910 and immediately set out to devise the course and the means

of implementing it until the buildings were erected (1916).

In the University of Western Australia, Sir Winthrop Hackett, in 1913, gave the sum of £18,000 for the endowment of a chair of Agriculture and in 1914 Professor J. W. Paterson started teaching under the Faculty of Science. A separate faculty was not created until 1937.

In the University of Queensland the Faculty began in 1927 with Professor J. K. Murray who was also Principal of the Agricultural College and High School at Gatton. He had with him three part-time lecturers. The relations with the Science Faculty were close and were maintained by the energy of the first Dean—the indefatigable Professor of Biology—the late Dr. E. J. Goddard.

Employment of Graduates

In its early stage each agricultural school went through a period of uncertainty as to whether its graduates would obtain employment in some direction for which their training fitted them. Unless this occurred, there was little purpose in maintaining the course. The agricultural colleges trained men for ordinary mixed farms; large estates involving complicated systems of management such as were common in Britain, were lacking in Australia, and at that time, the amount of really scientific knowledge capable of direct application to farming was relatively small. Plant breeding on modern lines was in its infancy, the study of pastures had scarcely begun, soil knowledge was unco-ordinated and largely rule-of-thumb, vitamins were unknown, mineral deficiencies were but dimly appreciated, and the fact that plant ash contained a wide variety of elements in small amounts was usually attributed to chance, or inefficiency in sampling or analysis. The idea that business firms might do worse than employ graduates on their staffs had scarcely been conceived. The only openings left were therefore in the educational field and in government departments of agriculture or stock. How were graduates to be appointed to the latter services when the profession was not recognised and the public service method of recruitment was the vogue?

New South Wales developed the system of cadetships, holders of which were nominated for the course by the State Department and were under a bond to serve with the Department for five years after graduation. This system was part of the original agreement with the University. In Victoria, the Agricultural Education Acts of 1920 and 1923, which provided a building and an annual endowment for the Faculty, also enabled the Minister to appoint a limited number of men to certain state departments on contract, and without reference to the Public Service Board. This system put the Melbourne School on its feet. In South Australia, provision for employing graduates in the State Service was not made until 1927, and was later withdrawn, consequently the number of students has remained small. In Perth, where the relation between the University School and the Department has been close, the latter has usually been ready to absorb graduates when positions were available.

The increasing tendency of business houses to employ university graduates has resulted in wider fields of employment developing. This has been very marked in Melbourne, whilst in Sydney numerous graduates have entered the teaching profession which seldom occurs in Victoria. The gradual expansion of the activities of the C.S.I.R. absorbed many, and other commonwealth departments have called for their services in various capacities.

The Practical Side

Each School had to face certain fundamental problems which are common to every institution dealing with agricultural science. First among these is the problem of how to give training in the practical side of agriculture. The question is not merely one of how to give it, but also at what stage in the course shall it be given, and how intensive shall it be. All the possible methods have been

tried. In Sydney work done on approved farms has been accepted. Melbourne first sent its students to Dookie; later they had special courses at, and lived on, the State Research Farm at Werribee. This was not found to be altogether satisfactory and during the war the second year again went to Dookie. Adelaide used Roseworthy, Perth Muresk, and in Queensland Gatton is used for the final year. No system is perfect; if the students go to a college or farm early they are scarcely sufficiently advanced to appreciate the scientific aspects of farming, and if they go at the end of the course they are liable to be troublesome and superior in attitude at a college. If they go to private farms, they do not usually get a broad enough training, and if they go to a college they sometimes become restive because they feel they are not doing enough of the manual work themselves—a difficulty which is quite insuperable where there are between 50 and 100 able-bodied young men who have to be found man-sized tasks every day of the week. Adelaide tried the experiment of sending them for two or more days each week in each year of the course after the first; but this proved too strenuous. It is certain that, under the system of using the colleges, every agricultural student has a good opportunity to learn a very great deal about the practical side of agriculture—and some take that opportunity.

The Problems of Specialisation

The great breadth of a sound course in Agricultural Science, which is one of its greatest virtues, is also the root cause of one of the greatest difficulties of every agricultural faculty. How is this large range of subjects to be covered? And to what degree of intensity? How far is time to be allocated to the basic sciences? And how deeply should the course go on the applied side? Overseas, in some university agricultural schools, the basic training in, say, chemistry, is given by agricultural chemists in the school. Under such circumstances the tendency for the specialist to forget that all his knowledge is based on pure science usually results in a disastrous course. Australian universities have generally avoided this difficulty. On the other hand some of them incorporate pure science courses in their syllabus to a much greater extent that others. For instance, it is unquestionable that agricultural graduates would often find a lengthy course in plant systematics of value, but the time and mental energy required for such training usually means that a specialised course on the systematics of the *Gramineae* and a passing reference to some other families is all that can be included. A clear idea of the outlines of plant physiology is an essential not only to the agricultural botanist but also to the agronomist if his mind is to think clearly on crop development and behaviour under various treatments. It is certain that a basic knowledge of statistics should be part of the equipment of every agriculturist, but a statistician will almost certainly demand about ninety hours of instruction for the subject, whilst experience suggests that even then less than half the class will manage to make sufficient progress to justify this allocation of time. How many hours should be devoted to climatology? Should every graduate have had training in such subjects as horticulture or animal diseases? What should be the standing of economics in the faculty.

These problems have been answered in a variety of ways by the various universities. To some extent the intensity of instruction in each subject has been affected by the personnel available for the teaching. A successful specialist in any subject at a school naturally tends to build up a research group around him and to set higher standards in his particular subject.

Although the presence in the faculty of a specialised lecturer on the agricultural aspects of a subject is more likely to lead to a suitable group of research workers, this is not invariably true, for in some

subjects — e.g., biochemistry — the research front on the agricultural side is so close to the general research front that agricultural graduates can well be trained in a university school belonging to the Faculty of Science. The same is true in some branches of entomology, bacteriology or plant physiology, but would be less valid in many branches of agricultural chemistry.

The wide range of topics in which the effectively trained graduate in agricultural science should be trained makes it most difficult for the faculties to obtain adequate staff. Generally, the money available to them is insufficient to support a full-time lecturer in each subject. The general principles followed have been to keep teaching in the basic scientific studies in the pure science school concerned, to appoint specialist full-time lecturers in those subjects which seem most important, and to use part-time lecturers from government departments or from other faculties for the balance of teaching. Under these circumstances the maintenance of satisfactory relations with state departments has been an important factor in the success of the schools. Many of the lecturers giving these special courses bring to their teaching a wealth of practical experience which the full-time university teacher can seldom command; provided the lecturers concerned have themselves acquired a sound scientific approach the result can be in every way satisfactory. The present position of the various faculties of agriculture in respect to full-time *lecturing* staff is as follows:—

	Syd.	Melb.	Adel.	Perth	Bris.
Professors and Assoc.-Professors .	2	2	4	1	1
Senior Lecturers ..	7	3*	4	1	1
Lecturers ..	2	1	—**	3	1

*Raised from 1 to 3 as a result of the increased grant under the 1949 Act.

**All other teachers are ranked as lecturers.

No attempt is made to tabulate the strength in part-time staff as the amount of time devoted to such work by individuals varies greatly, while a survey of periods taught would also be complicated by the varying arrangements for the practical year.

One way of overcoming these difficulties, which follow from the breadth of the course, is to allow a considerable amount of specialisation in the final or last two years of the course. This solution is eminently satisfactory if the students have a clear idea as to the direction in which they are likely to obtain employment after graduation. If this is uncertain it is probably safer to keep the course unspecialised and at a lower level of intensity in each subject, recognising that the graduate with a first degree will require further training before he can be thought of as a research worker. Sydney allows considerable selection of subjects in the fourth year, Melbourne and Perth a very limited amount, while in Adelaide's new course and that at Brisbane no choice is permitted.

The Length of the Course

An alternative method of solution is to add a year to the course, so as to give time for more advanced study for every student. This not only increases the cost of the course by a quarter, but also defers the date at which the graduate can start earning and cease to be a strain on the family resources. The latter point has become specially significant since the great increase in taxation during the recent war; particularly as the cost of a university course for a dependant is not an income tax deduction after the age of 21. Finally, it seems clear that if the foundations of instruction in the subjects are sound, and the detailed instruction as far as it goes, is clear, then a four-year course, despite its deficiencies, is still sufficient training for many of the positions in which graduates are employed. If they have need to go further they will at least know the sources from which ad-

ditional information can be obtained. A close comparison with the veterinary profession in which, by virtue of its legal obligation, each member must necessarily be fully informed up to a basic minimum standard in many subjects, is scarcely valid.

Sydney and Adelaide have adopted a four-year course with a fifth year for an honours degree. Perth and Brisbane also award honours degrees which normally require a fifth year of work. Melbourne abandoned its "final honours" examination some years ago, and has preferred to offer a master's degree which can be obtained after one, or more usually two, years of advanced study in a specialised field.

The Faculties in Relation to Research

The unspecialised four-year course requires that the school shall be able to give training at a higher level in a variety of subjects. In view of the restricted number of subjects in which the faculties have full-time lecturers this is a matter of some difficulty unless satisfactory arrangements can be made for work under officers in allied subjects in the science faculty or in a state department.

The various schools show wide differences in relation to research according to the extent to which they have been supported by private benefactors, the C.S.I.R., or state parliaments.

In many subjects the value of formal teaching for fifth-year students is dubious. Usually, training at this stage is most effective when a considerable part of the student's time is occupied with the investigation of some simple problem, or by the student taking part in a team engaged on a larger piece of research. The facilities for research in a school are therefore important in regard to the advanced training of students as well as in regard to the maintenance of a lively spirit of enquiry throughout the whole fabric.

Generally speaking, Australian universities are not well endowed for research purposes. Funds from government sources have always been meagre, and private endowments have been an important source of support in some cases. The magnificent bequests of land and money made by Peter Waite to the University of Adelaide in 1924 is the outstanding example in the field of agricultural science. This was followed by further bequests from other sources, while the State Government agreed to reinforce the funds received in this way. Thanks to these gifts, the late Professor A. E. V. Richardson was able to build the work of the Waite Institute on firm foundations, which were reinforced on the soil side by Professor J. A. Prescott, under whose leadership at the Waite the Soils Division of the C.S.I.R. was also formed. No other agricultural faculty in Australia has had anything like the same monetary resources at its disposal.

The only other school with a special research institute is that of the University of Western Australia. Here the Institute of Agricultural Research was founded in 1938 when the School was given twenty-five acres on the Crawley site and a new building was erected partly by the University and partly by the State Government. Numerous business firms have supported the work, much of which has been connected with the sheep industry. In addition, the Hackett Scholarships have been of great value in supporting research students.

At Sydney, the C.S.I.R. assisted in the support of the research on plant breeding in relation to disease resistance.

The Melbourne School has benefited from several benefactions of which the chief were due to the late Sir John and Lady Higgins, while the State Government provided £500 a year for agricultural research under the Act of 1928 and increased this to £1,000 under the Act of 1949. The School has received no support from C.S.I.R. but one project was supported by Wool Board Funds and C.S.I.R.O. has recently agreed to support one worker.

Future Prospects

The further development of agricultural systems in most districts of Australia is a question of improved technical efficiency based on a scientific approach to problems of soils, plants and animals. It is a matter of brains, not brawn, consequently the future development of the agricultural faculties should be assured always provided that they continue to recognise that their chief function is to train students for applied positions in the public service and in commerce. Many university faculties have a tendency to regard research work as their main objective. While everyone who understands the inner spirit of university life will readily admit that research is an important part of every effective faculty, some are apt to forget that the purpose of almost all the applied faculties which have been created in Australia is to train students for their respective professions.

On the research side the future seems reasonably bright as C.S.I.R.O. has given some indication of having at long last realised that it will not obtain a supply of well-trained research workers unless it takes steps to enable and encourage university schools to undertake the training of their better students at the post-graduate stage.

The writer wishes to acknowledge gratefully assistance from Professors McMillan, Teakle, Trumble and Underwood, and to Mr. O. St.J. Kent for providing much background detail and to Mr. E. A. Jennings for assiduous delving.

THE AUSTRALIAN INSTITUTE OF AGRICULTURAL SCIENCE (1935-1951)

By G. de VAHL DAVIS

It would be unfair to the achievements of the past 16 years, to suggest that in 1951, Jubilee year of the Commonwealth, the A.I.A.S. is "standing at the cross-roads" or doing any of the other things hallowed by cliché and indicating a state of emergency. Yet a Jubilee is as good an occasion as any other for stocktaking, whether on a national or institutional plane, and there are few who could regard the present status of Institute affairs with any proper degree of complacency—and this, be it repeated, despite an array of positive accomplishments which, for proper appreciation, merit the summarised presentation which follows.

HISTORICAL

As a due preliminary, however, it might be fitting to relate the story of the Institute's creation. Generated in the early thirties by interstate correspondence between G. de V. Davis in Sydney and Leith Gillespie in Melbourne, the idea of a corporate association of agricultural scientists was discussed by a gradually widening but still eclectic circle in those and, later, other state capitals. The matter moved ahead when, to quote a 1933 letter, "a man named Vasey" came to Sydney and visited Eric Edwards. The writer, as president of the Sydney University Agricultural Graduates' Association, had the idea endorsed by that body and, with the support of the Melbourne University Agricultural Society, issued invitations to a conference in Melbourne where 20 delegates from organizations or groups of individuals throughout the Commonwealth, adopted a draft Constitution and also accepted the offer of the Sydney University Agricultural Graduates' Association to hand over its existing journal and continue publication in the interest of the new body which was at that stage given its present name.

There can be no danger of making invidious distinctions in here recording the names of those 20 pioneers (styles and titles as of 1935):—

Australian Capital Territory: Dr. B. T. Dickson, Dr. I. Mackerras and G. A. Currie.

New South Wales: Prof. R. D. Watt, G. de V. Davis, E. T. Edwards and H. J. Hynes.

Victoria: A. B. Hackwell, W. B. Miller, F. M. Read and A. J. Vasey (also Prof. Wadham, unattached to any Branch).

South Australia: Dr. J. G. Davies, Dr. I. F. Phipps, C. S. Piper and H. C. Trumble.

Queensland: Prof. and Mrs. J. K. Murray.

Western Australia: H. G. Andrewartha and A. J. Roberts.

Tasmania: E. F. Fricke.

With few exceptions, all of these took a prominent part in Institute affairs. Five have been Federal presidents, four others have held Council or Journal office, most of the others have been Branch Presidents and, what is more significant and admirable, most of them still retain active interest. Rounding off this history, the story of Institute growth by figures, a complete list of office-bearers from 1935 to date and a list of medallists will be found below. Those who know *will* look and newer members *should* look with due respect and affection at the team Vasey and Twentyman who, as Honorary

Corporate Membership (five-year intervals)							
	A.C.T.	Q'ld.	N.S.W.	Vic.	S.A.	W.A.	Tas.	Total
1935	21	12	40	18	39	—	12	143
1940	33	58	125	112	59	54	17	458
1945	34	60	168	150	63	70	19	587
1950	58	86	218	204	104	95	31	769
Student Members								
1950	—	21	96	14	25	43	—	199

Secretary and Honorary Treasurer, not only held the fort for the first (and hardest) ten years but, at the same time, and with the aid of their Presidents and other colleagues, expanded and strengthened the structure and gave it the potentialities which it has today, for future greatness.

Office-Bearers

Presidents

A. E. V. Richardson .... 1935, 1936.
S. M. Wadham .... 1937, 1938.
R. D. Watt .... 1939, 1940.
J. A. Prescott .... 1941, 1942.
S. A. Currie .. .. 1943, 1944.
B. T. Dickson .... 1945, 1946.
G. de V. Davis .... 1947.
H. F. Bell .... 1948.
J. R. A. McMillan .... 1949.
F. W. Hicks .. .. 1950.
J. G. Davies .. .. 1951.

Hon. General Secretaries

A. J. Vasey .... 1935–1944.
F. T. Bowman .... 1945–1947.
L. F. Mandelson .. .. 1948.
G. A. McIntyre 1949–

Hon. General Treasurers

R. T. Twentyman .... 1935–1944.
F. C. McCleery .... 1945–1948.
W. Ives .... 1949.
A. V. Hill 1950–

Hon. Editors

H. J. Hynes .... 1935–1941.
F. T. Bowman .... 1942–1944.
Lilian Fraser .... 1945.
D. B. Adam .... 1946–1947.
A. Shavitsky .... 1948.
A. Shavitsky-A. J. McIntyre (Joint Editors) .. .... 1949.
N. M. Tulloh 1950–

Hon. Business Managers

E. T. Edwards .... 1935–1937.
N. S. Noble .... 1938–1944.
N. C. Lloyd .... 1945.
C. S. Piper .... 1946–1947.
W. J. Webb .... 1948.
P. A. M. Bell .. .. 1949.
J. S. Orr 1950–

The Australian Medal of Agricultural Science

1948—Prof. S. M. Wadham.
1949—Prof. W. L. Waterhouse.
1950—Prof. J. A. Prescott.
1951—Dr. E. A. Cornish.

INSTITUTE PROJECTS

Apart from its domestic pre-occupations, necessarily great in a body still comparatively new, the Institute has devoted its attention to a series of projects. These have originated sometimes at Branch level, sometimes in Council and sometimes with the President for the time being, or some other individual. The general technique has been:—

(a) discussion and endorsement by Council;
(b) (i) reference to an ad hoc Committee within one, several or all Branches or
(ii) appointment of an ad hoc Committee of Council;
(c) eventual report(s) adopted, collated or amended by Council and circulated to Branches for
(d) (i) approval or otherwise by Branches or
(ii) instruction to Branch delegates at ensuing General Meeting;

(e) return to Council for such implementation as may be appropriate.

This procedure has been stigmatised as tedious, clumsy and likely to lead, at times, to the death of a given project, by inanition. These things may be wholly or partly true, but at least they have resulted in the eventual definition of a true 'average member reaction' and certainly every matter that has gone forward has had, if not unanimous endorsement, at least the support of a clear majority of Branches and therefore, presumably, of individual members.

Some of the earlier major projects had the be left uncompleted at the outbreak of war with the consequent diversion of member-interest to matters of more immediate concern. Some were brought to completion, but their implementation was frustrated by governmental apathy or opposition. Others again were followed right through and implemented to an extent limited, however, by a seeming loss of interest. Finally, a significant proportion has met with a degree of success as high as could have been contemplated.

The Population Survey

The earliest of these projects arose from the first Presidential Address in which the late Prof. A. E. V. Richardson suggested co-operation between Institute members, economists and geographers in an attempt to survey agricultural resources, forecast their maximum productivity and thus assess the population potential of the Commonwealth. Considerable progress was made with this work, notably in South Australia and Victoria, both of which Branches reported in the *J. Aust. Inst. Agric. Sci.*, **5**: 1, 1939, with some detail.

The work continued for some time after this and references were made at the 2nd (January, 1939) and 3rd (November, 1940) General Meetings. At the last-mentioned, however, it was stated that the pre-occupation of members and others with national duties made progress difficult and it is doubtful whether finality was ever reached although the project was referred to the New South Wales Department of Agriculture (Division of Agricultural Economics). Incidentally, a revival of this project, in relation to post-war migration experience, would be timely.

Plant Quarantine

Another major project that stemmed from the early days of the Institute was an enquiry into the system of Plant Quarantine. This matter was pursued by Branch Committees but before the final collated report was presented, as planned, to the 4th General Meeting, a Commonwealth Conference was convened on the subject. At this, the Institute report was tabled and it formed the basis of many of the recommendations later submitted to the Agricultural Council.

Other Projects

It would unduly expand this necessarily brief survey to do more than merely mention some of the main projects that have been brought forward at Institute or Branch level. Such matters included: the need for specialised training to provide more personnel skilled in agricultural economics; the duty of the Institute to sponsor national and international conferences (which led to the Cereal Breeders' Conference at Adelaide in 1946); the need for a policy of publicity to establish the Institute more prominently in the public mind (a matter still meriting Branch action); the need for an Australian Journal of Agricultural Research (which led to the association of the Institute with the publications of the C.S.I.R.O.); the need for increased attention to Extension Services—a matter, strangely, that excited little attention beyond New South Wales where discussions may have contributed to the creation of a new Research Co-ordination Committee, the functioning of which, however, has not answered all the needs of a large section of Branch members; the need for

specialised training of agricultural engineers.

There are many more—the Journal of the Institute tells their story and its files are worth re-reading, if for this alone. They did not all meet with success, even to the extent noted above. Perhaps the classical failure was the effort to improve the facilities for the interchange of scientific personnel without loss of rights and privileges. In this, the Commonwealth has, seemingly right down to this day, maintained its status of a big and rather dominant brother, with the several States competing for the remainder of the available manpower and private enterprise still making frequent predatory raids.

The "Forster-Vasey" Project

Mention of this topic leads, inevitably, to yet another project almost as old as the Institute, but evergreen and, probably, ever-lasting. From the time of the famous, almost traditional, Forster-Vasey report, the problems of "Salaries and Status" have loomed large in Institute discussions. Members are apt to wax, according to temperant, gloomy or sarcastic when this is mentioned, but veterans—i.e., graduates of 15 years' standing or more—must admit that conditions are better now than before and it could not be doubted that Institute and Branch submissions have had a beneficial, it not decisive, influence.

TRADE UNION—OR WHAT?

To what extent is this pre-occupation justified? Is the Institute—ask this question and run for cover!—a Trade Union? The question is valid and not very difficult to answer. Webster defines a trade union as "a voluntary association of working people organised to further or maintain their rights, privileges and interests . . .". Begging the question, if one may, in relation to the term "working people", surely these were amongst the considerations in the minds of the not notably militant or radical founding fathers.

This writer holds it entirely proper that the Institute Corporate concern itself, *inter alia,* with the material welfare of its membership. There was never a saying more applicable to modern trends than the "labourer is worthy of his hire". Freedom from excessive economic concern and the prospect of a moderately expanding future leading to a degree of security—these things can provide *mens sana* in the *corpore sano* of men who are expected to devote their lives not to their personal gain but to the welfare of the Commonwealth, in the broadest non-political sense of the word.

WHITHER NOW?

This, then, is your Institute in this Jubilee Year. With its achievements and its failures, with its efforts and its occasional apathy, it has never departed from the right and abiding principle of scientific integrity. Perhaps the time has come for it to adopt a more vigorous policy—to add a leaven of progressive activity into its desirably conservative stability. Perhaps it has outgrown the capabilities of honorary officers and now needs full-time service. Perhaps—and this was hinted elsewhere—the Melbourne General Meeting was wrong and Presidents should be given, as formerly, two years in which to see their projects through to or close to completion. These are questions that the members will answer at the right time and in the right manner.

Whatever the decision, with so worthy a record in its first 16 years, the Institute can look towards a future that holds the promise of fulfilment for, as it was truly said,

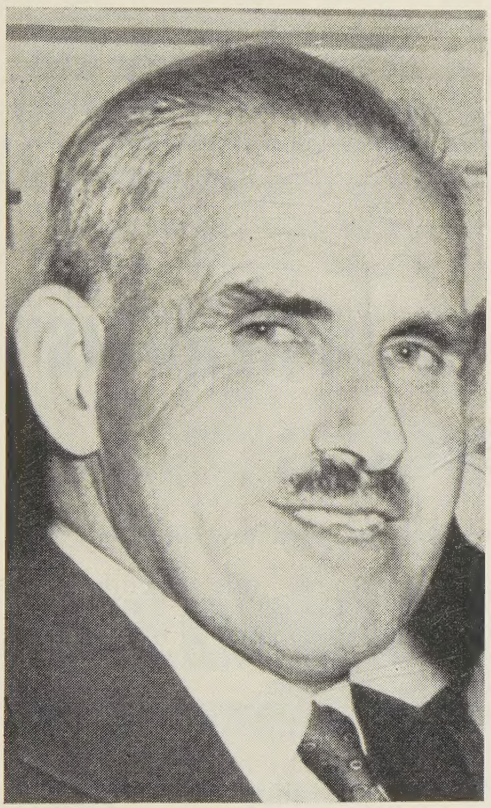
"The A.I.A.S., partly through its own achievements and partly by the lustre it borrows from distinctions earned by its members, is now a feature in the Agricultural scene of the Commonwealth."

Obituary

MR. D. B. ADAM

It is with sincere regret that we record the death in Adelaide on February 22, 1951, of Mr. David Bonar Adam, Reader in Plant Pathology at the Waite Agricultural Research Institute, University of Adelaide.

Born in Scotland in 1900, Mr. Adam was educated at Scotch College, Melbourne, Longerenong and Dookie Agricultural Colleges and the Melbourne University.



Graduating with first class honours in agricultural science in 1922, he entered the Victorian Department of Agriculture where he commenced studies on problems associated with cool storage of fruit.

Following upon his appointment as Vegetable Pathologist in 1925, Mr. Adam had the opportunity of visiting research centres in Europe and America and on his return to Australia there followed a fruitful period of research in Plant Pathology, his attention being continually directed to the more difficult fundamental problems of that science.

In 1934, he accepted appointment as Head of the Department of Plant Pathology at the Waite Agricultural Research Institute—a position he held until his death.

Shortly after his appointment to the Waite Institute, Mr. Adam began to study the important disease of wheat known in Australia as "Take-all" or "Whiteheads" and caused by the soil-borne fungus *Ophiobolis graminis*. He was led to take up this work not only because "Take all" was a serious disease of wheat crops in South Australia and elsewhere, but also because the disease presented many puzzling features in both its mycological and agronomic aspects. The first result of research during early years was to emphasise the complexity of the problem. A less tenacious mind, one more easily satisfied with "near enough," one less fully endowed with the scientist's quality of patiently seeking a full and satisfying understanding of natural phenomena, might have been satisfied to present a blurred half-picture. Not so David Adam. Step by step, and year by year, he patiently built up a background of knowledge until, shortly before his death, he felt he was at last in a position to see

"Take-all" in its true perspective. It is a tragedy that he did not live to complete the writing of the story.

Mr. Adam had a wide experience and sound judgment not only in his own special subject of plant pathology but in other branches of agricultural science as well.

David Adam was a good friend. His time was always fully occupied but he was never too busy to take a real interest in another's problems as they were laid before him. We shall long remember him for his fine scientific qualities and above all for his unfailing good fellowship and the warmth of his humanity.

Mr. Adam was a foundation member of the A.I.A.S. He was active in its affairs, serving in the South Australian Branch as committee man, editor and branch president.

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